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Index of abbreviations

a	weighting factor
ACEA	European Automobile Manufacturers Association
ADF	Augmented Dickey Fuller
BMUB	Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit
	(Federal Ministry for the Environment, Nature Conservation and Nuclear Safety)
BMVIT	Bundesministerium für Verkehr, Innovationen und Technologie
	(Federal Ministry of Transport, Innovation and Technology)
BMW	Bavarian Motor Works
BMWi	Bundesministerium für Wirtschaft und Energie
	(Federal Ministry for Economic Affairs and Energy)
CAM	Center of Automotive Management
CARS	Competitive Automobile Control System
cf.	compare
Co.	Company
CO_2	Carbon dioxide
DF	Dickey Fuller
DM	Daimler
EC	European Community
ECE	Economic Commission for Europe
EEA	European Environment Agency
EEC	European Economic Community
etc.	et cetera
EU	European Union
FD	Ford
ff.	and the following
g	gram

g/km	gram per Kilometre
GM	General Motors
i.e.	in other words
JAMA	Japan Automobile Manufacturers Association
KAMA	Korean Automobile Manufacturers Association
kg	Kilogram
kWh	kilowatt hour
M	Mass of the vehicle in kilograms
M_0	Corrected value after the changed weight
Mio.	Million
NAFTA	North American Free Trade Agreement
NEDC	New European Driving Cycle
No.	Number
OICA	The international organisation of motor vehicle manufacturers
OLS	Ordinary Least Squares
PG	Peugeot
R-101	Regulation 101
RN	Renault
SOP	Start of Production
SP	Stock Price
tsd.	thousand
UNFCCC	United Nations Framework Convention on Climate Change
VDA	Verband der Automobilindustrie
	(The German Association of the Automotive Industry)
VW	Volkswagen
WLTP	Worldwide harmonized light-duty vehicle test procedure
Xetra	Exchange Electronic Trading from the "Deutsche Börse"

1. Introduction

The global passenger car industry is one of the most significant factors of issuing greenhouse gases. Therefore nearly all industrialized countries are trying to adjust this sector with several regulations. In the European Union the transport sector is responsible for one quarter of the overall CO_2 emission, in contrast to even a third of carbon dioxide emission in the United States.[1] That is one of the reasons why the catchwords sustainability and environmental protection are becoming more and more prevalent. The reason why the automobile industry is mostly measured by the carbon dioxide emission will be elucidated later.

The last three decades have shown enormous changes in the evolution of car technologies, especially in the emission of CO_2. Due to numerous attempts by the European Union and individual regulations by the countries, to restrict the excessive air pollution, the passenger car sector faced many different strategies. Crucial regulations imposed by the European Union forced the manufacturers to modify their CO_2 emissions to accomplish the guidelines. The two key ordinances were announced in 1999 and in 2008 with respect to the Kyoto Protocol, the Untied Nations framework convention on climate change. In particular the announcement of 2008 is interesting to observe, if there was any influence on stock prices in the period of publication. These independent commitment by the European Union imposed restrictions to reduce the Greenhouse Gases by 20% from the benchmark in 1990. [2]

In this research paper I am going to investigate the improvements of the car manufacturers technologies regarding the limitation of the CO_2 emissions and in further consequence if there are any repercussions on the stock prices.

The study can be split in 2 main parts, the theoretical and the empirical part. In the first part I will introduce some fundamental information regarding CO_2 emission and the reason for the legal conditions. Subsequently the legal restrictions will be illustrated, accompanied by a chronological overview of the developments since the idea of CO_2-emission reduction was born by the legislators. As some of the world's most popular automobile manufacturer, for instance BMW or Daimler, are known to be extremely environment unfriendly in values of CO_2 emission, it will be very interesting to examine the reactions of these manufacturers with regard to the legal restrictions.

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1 Cf. Elmer, 2010, pp.161-162

2 Cf. Fontaras, 2012, p.720

These circumstances are fundamental for the empirical part, which will on the one hand side investigate the speed of achieving the required CO_2 values. Therefore I will apply the so-called Bass-Diffusion-Model, which is a model to measure the pace and the timing of implementing new technologies. The results of this kind of measurement should deliver an interesting outcome in comparison with the second empirical examination. The second main investigation affects the correlation between the reduction of CO_2 emission values and the stock prices of the various manufacturers. The underlying hypothesis will proof if a reduction in the emissions is going to raise the long-term profitability of a company in terms of the stock price.

For the underlining data I used a data set provided by the University of Vienna with nearly twelve thousand data of the various car manufacturers. The data stream for the stock prices was used by the yahoo finance platform. The aim of this study is to examine correlations of CO_2 emissions and stock prices.

The last part will give the conclusion where I will recapitulate the working paper and discuss the outcome compared to the hypotheses made and finally give an outlook for possible future research.

2. CO_2 Emission

Initially it should be clarified why the emission of carbon dioxide (CO_2) is such an important factor for our environment and is mentioned firstly in most of the climate discussions.

Fundamental CO_2 is an invisible and odourless gas, which is contained in the air with a volume share of 0,03% and is also attached to many drinks.[3] These facts do not seem worth considering; indeed the global primary energy consumption is covered mainly by fossil energy sources. Due to the combustion of fossil fuels carbon dioxide is released and builds up in the atmosphere.[4]

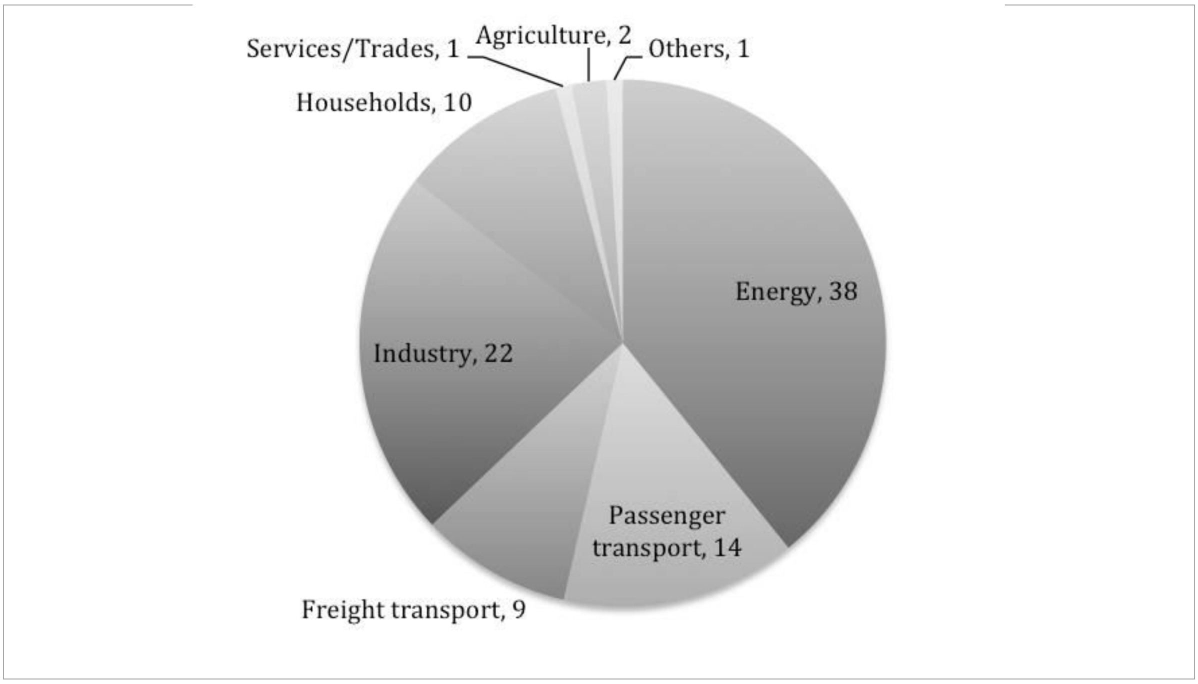

Figure 1: CO_2 Emissions in Europe in 2007 by Sectors (Data basis: EUR10b) [5]

The enormous increase during the last decades of greenhouse gas effect has strongly contributed to the progressing climate change.[6] This is the main reason of hardly trying to reduce these emissions. In particular, between 60% and 70% of the entire anthropogenic greenhouse gas effect is assigned to the CO_2 emission. Anthropogenic greenhouse gases is purely the share which is caused by the humans, whereas the naturally greenhouse effect has created an equilibrium temperature, namely the

3 Cf. von Gadow, 2003, p.22

4 Cf. Zwingmann, 2007, p.12

5 Own representation based on BMWi, 2012, p.11

6 Cf Frenzel & Pfennig, 2014, p.1

difference between the shined-in and reflected solar energy. Owed by human culpability this balance is extremely endangered, which in turn explains the hazard of this gas for the environmental pollution.[7]

Therefore it makes sense, that CO_2 emission is the most familiar expression when there are debates about air pollution. Logically, the politics have aimed the simplest way to treat the biggest source of emission, in order to regulate the greenhouse gases. The reason therefore is that the origin of the carbon dioxide emission is well known, in contrast to other greenhouse gases, and facilitates therefore the prevention of the greenhouse gas effect. The particular importance of CO_2 emission for our environment has resulted in the fact, that all greenhouse gases, which are harmful for our climate, are measured in carbon dioxide.

In order to get a better feeling for the rapid increase of CO_2 emissions a review of the last century will help tremendously. Whereas the worldwide output in 1931 with 3.4 billions of tons CO_2 was vanishingly low in contrast to approximately 35 billions in 2012.[8] The absolute top of the world country is China with incredible 29% of the global emission, followed by the United States with just 15% and the European Union (27) with 11%.[9] [10]

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7 Cf. Zwingmann, 2007, p12

8 Cf. Statista, 2016a, Last accessed: 15.10.2015

9 Cf. Statista, 2016b, Last accessed: 15.10.2015

10 Cf. Olivier, Janssens-Maenhout, Muntean, Peters, 2013, p.4

2.1 EU Regulation

The beginning of the common climate protection was in June 1992 in Rio de Janeiro at the United Nations Framework Convention on Climate Change (UNFCCC) were the European Council established the decision 94/69/EC. Target of this Climate Convention was the common protection of the atmosphere and its stabilization. Due to the vast amount of anthropogenic air pollution the climate system was known as sorely affected if the quantity of greenhouse gases would not be reduced.[11]

The European Union started in 1995 to develop a strategy, to reduce CO_2 emissions and to decrease the average fuel consumption, for the passenger car industry. Initially the European commission have set a target of an average CO_2 emission of 120g/km (gram per kilometre) for passenger cars till 2005 and at least till 2010. At that time European law did not regulate the strategy, a model based on three pillars, since 1995, observed indeed the strategy.

Firstly, the industrial associations of the car industry provided a voluntary undertaking of attaining an average CO_2 emission of 140g/km for new passenger cars till 2008 for the European Automobile Manufacturers Association (ACEA) and till 2009 for the Japan and Korean Automobile Manufacturers Association (JAMA and KAMA). Secondly, compulsory declaration of the fuel consumption was imposed by the commission, in order to disclose such important environmental information to the end customers. Thirdly, the relevant authorities announced tax advantages with regard to passenger cars with low fuel consumption.[12]

2.1.1 Status report –observation

The progress report, which was announced in 2002, showed that the ambitious goals, imposed by the European commission were net as successful as believed. Partially the targets were highly motivated and partly the fact that there was no regulation by law yielded the somewhat sobering result of 167-170 g/km CO_2 emission in 2001, as compared with 186g/km in 1995. Through this preliminary report it appeared nearly impossible to reach the target for 2005, but the alternative goal till 2010 was on target if the required actions would be taken and the combined efforts would be kept up. In particular the self-commitment of KAMA had some room for improvement in contrast to the ACEA and the JAMA, who progressed steadily. In addition a lately

11 Cf. EU Commission, 2011, p.11

12 Cf. EU Commission , 2001, p.3 ff

announced strategy for passenger car taxation by the commission, should also help the community to reach its target. [13]

Due to the commencement of the Kyoto Protocol in February 2005, the European Union committed itself to reduce theirs greenhouse gas emissions. The ratification, which was negotiated 1997 in the Japanese location Kyoto geared towards the prevention of global warming. By reducing predominantly the carbon dioxide, generated through combusting of fossil fuels, but also methane, laughing gas and fluoride gases. The European Union, in particular, committed itself to cut its merits from 1990 by 8% within a period of time between 2008 and 2012.

The official guideline to reach the requested air quality targets was enacted in the regulation 98/69/EC by the EU. The main message of this requirement was the declaration that only cars that met the Euro IV emission standard were allowed to receive a car registration. The declaration day was the 1.1.2005 and was validated for all new cars within the European Union.[14]

In the context of the previous regulation by the EU, the community suggested in January 2007 to reduce the greenhouse gases in industrial countries by 30% till 2020, as measured by the values of 1990. The Union tried to achieve this in the framework of international proceedings. Independent of these purposes the European collective has self-imposed a mandatory target of 20% less than in 1990.

This highly important decision in 2007 will constitute the starting year in the empirical part. Due to this publication the official starting signal should be given and play a significant role in the behaviour of the individual car manufacturers. In particular, the respective effort regarding the reduction of CO_2 emissions should be extremely attractive to investigate.

Concerning the passenger car industry the next essential announcement was in February 2007, when the European commission publicized two messages whereby the first was a further report regarding the progress of the implemented strategy for passenger cars and light commercial vehicles. Similarly to the report in 2002 the community had to perceive that the desired aspiration of 120g/km till 2012 was not

13 Cf. EU Commission, 2002, p.4 ff

14 Cf. BMVIT, 2007, p.164 ff

feasible anymore. At least the common target for 2008 and 2009 with around 140g/km of CO_2 emission seemed to make improvements. [15]

The second part of the communication was an implementation plan for a competitive automobile control system (CARS) in the 21st century. The assignment of this working group was the future direction of the automobile sectors policy. In particular, CARS 21 geared toward a useful collaboration between the several policy areas, together with the preservation of public interest like safety and environment protection. Furthermore it should develop some regulations in order to lower the burden the automobile industry has to bear with.

The working committee was founded in 2005 and composed of the most important interest groups regarding the significant policy affairs of the automobile industry. The European member countries, the industry, non-governmental organizations and the European parliament formed the CARS team.[16]

2.1.2 Mandatory legal framework

In December 2008 the Council of Europe and the parliament have agreed upon a mandatory regulation to reduce the CO_2 emission for new passenger cars. When the enactment, number 443/2009 EC, became law in April 2009 it was simultaneously a very important milestone for the automobile industry, as the planning certainty for new technologies was constituted. An average of 95g/km on CO_2 emission till 2020 was defined, which should coincidentally help the European car manufacturers to stay competitive in a world of efficient cars.17

In the following section there will be the key elements of the regulation highlighted.

1. The target value has been determined with 130 g/km for all new registered passenger cars measured after the regulation Number 715/2007 EC. The merit should be reached through improvements of the motor engineering as well as innovative technologies.

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15 Cf. EU Parliament, 2009, p. L140/1

16 Cf. EU Commission, 2007, p.7 ff

17 Cf. BMUB, 2009, p.1

2. Suggested from the commission there will be a 60% curve applied, with a special treatment beginning in 2016. A formula will regulate the permissible CO_2 emissions for each new registered passenger car from 2012 to 2015 and as of 2016 with a corrected weight-increase factor.

From 2012 to 2015:

Specific CO_2-Emissions = 130 + a × (M - M0)
Where we use:
M = mass of the vehicle in kilograms (kg)
M_0 = 1372,0
a = 0,0457

From 2016:

Specific CO_2-Emissions = 130 + a × (M - M0)
Where we use:
M = mass of the vehicle in kilograms (kg)
M_0 = corrected Value after the changed weight
a = 0,0457 [18]

The target value of each manufacturer is depending on the structure of the new vehicles launched on the market. The allowed CO_2 emissions of the new passenger car fleet of the producers are principally conditional of four factors:

i. The European automobile fleet target of 130g CO_2/km
ii. The average weight of new vehicles sold by the manufacturer
iii. The average weight of sold new vehicles in the EU 27 countries in the period from 2008 to 2010. This was 1.372 kg in the current calculation period.
iv. The weighting factor *a*, which is responsible for the increase of emissions in relation to the vehicle weight. Currently this factor is selected in such a way that 100 kg additional weight are increasing the limit value by 4,57g CO_2/km

All these factors combine a linear relation, which is illustrated in the following figure. The used equation is as follows:

$$\mathbf{CO_2 = 130g\ CO_2/km + 0{,}0457 * (Vehicle\ weight\ in\ kg - 1.372kg)}$$

Due to this formula it is easily accessible for each manufacturer to calculate its individual target value by entering its average vehicle fleet weight into the expression.

18 Cf. EU Parliament, 2009, p. L140/12

Only with an average fleet weight of 1372kg the producer reaches the CO_2 target value of 130g CO_2/km. With deviating average weight the emission value will be above or below the threshold.

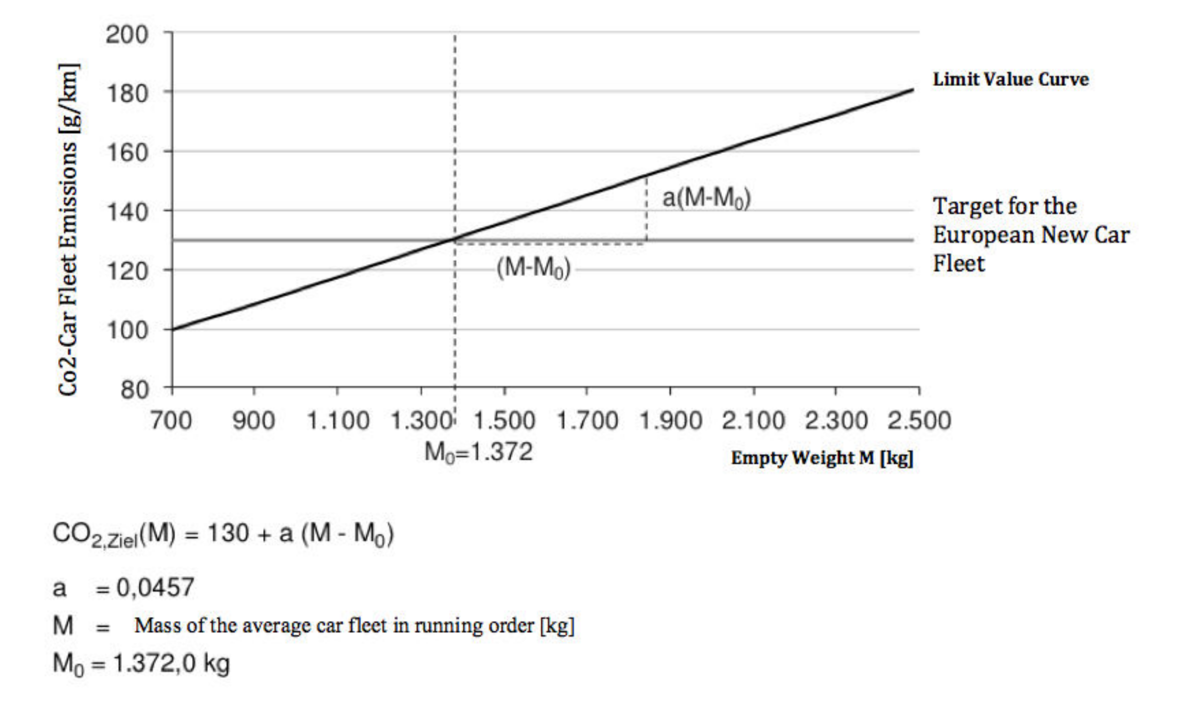

Figure 2: EU-Regulation for reducing the CO_2-Emissions of the new car fleet[19]

The reason for the implementation of the weighting factor *a* was the maintenance of the competition with different product portfolios across the automobile sector. A uniform target value for all manufacturers would be an improper regulation system. It has lad to a situation where the producers of small vehicles would not need to make a particular effort to achieve the objectives. Whereas, in contrast the manufacturers of heavy cars would have been chasing an utopian target. As the European streets are mainly frequented by smaller cars the regulation system would not be effective with a common threshold. Otherwise the heavy car producers would have been doomed to failure.

Ultimately the valid regulation with the weighting factor of 0,00457 enables the producers of heavy cars enhanced fuel consumption, however the required effort of reduction is more stringent for them.[20]

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19 Own representation based on BMWi, 2012, p.13

20 Cf. Puls, 2013, p.10

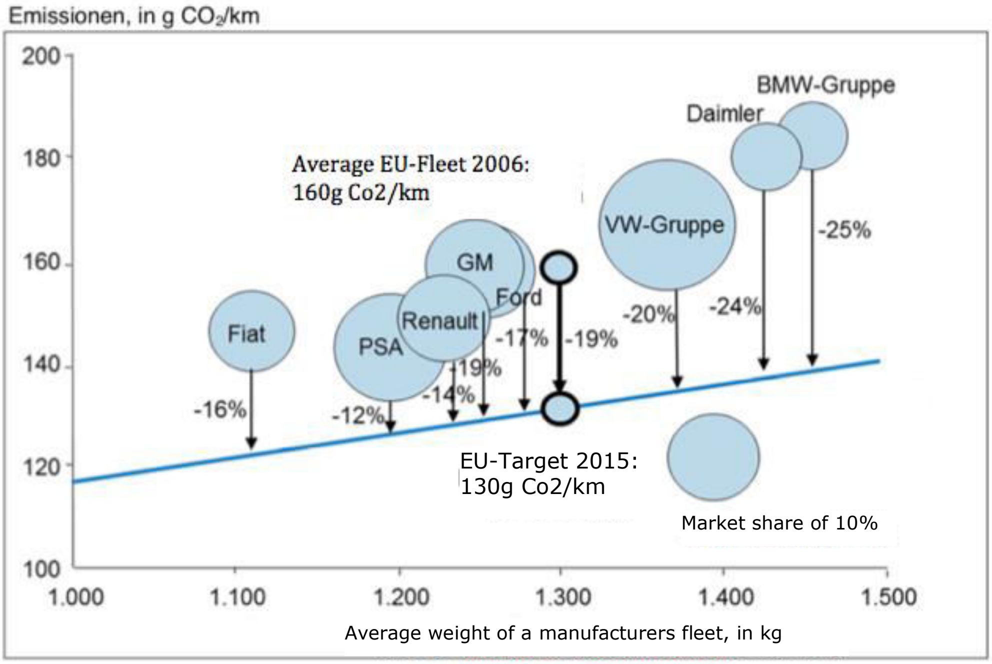

Figure 3: Required burden sharing for the period of 2006 to 2015 [21]

The above illustration shows in the centre the European average fleet value of 2006 with 160g CO_2/km evidently, while the target for 2015 is 19 per cent deeper with 130g CO_2/km.

Around this aggregate value the burden sharing of the several automobile manufacturers is plotted. It is clearly obvious that the upper middle class like the BMW Group, Daimler and also the Volkswagen Group have to spend substantially more effort on the CO_2 emission reduction in contrast to the producer of small and light cars.

3. The years from 2012 to 2015 will be encouraged with a phase in cycle. This period of time should help the car manufacturers to approach the CO_2 target values of their new cars.

   – 65% in 2012;
   – 75% in 2013;
   – 80% in 2014;
   – 100% from 2015.

21 Own representation based on VDA, 2009, p.20

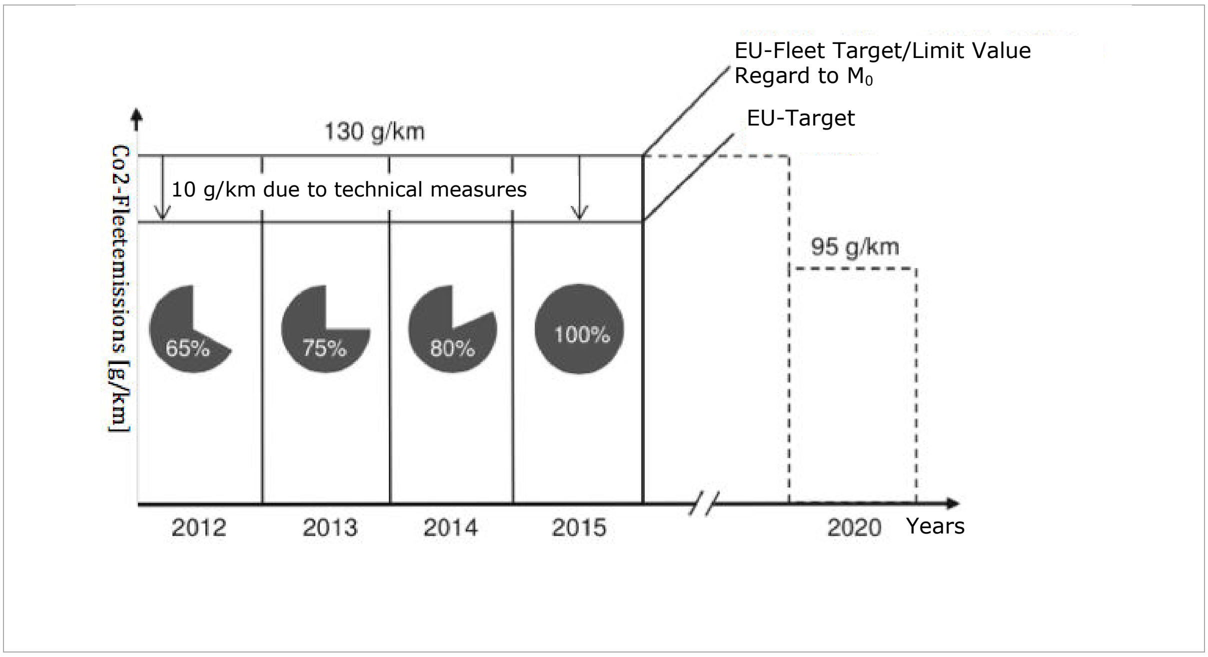

Figure 4: Phase-in for CO_2 target level (new car fleet)[22]

In addition to the defined CO_2 target for the average European new vehicle fleet the European commission wants to achieve further 10g CO_2/km through technical measures. The alternative measures to further reduce the objective of 130g CO_2/km are planned due to efficiency increase of air condition as well as the use of tire pressure monitoring, gear shift indicators, low resistance tires and biomass fuels.[23]

4. Regarding the financial penalties the recommendation from the commission was slightly changed particularly for narrow deviations.
   From 2012 to 2018 there is a progressively punishment for transgression from 0 to 3 g/km.

   a. 0 to 1 g/km accrue per g/km 5 €/g

   b. 1 to 2- g/km 15 €/g

   c. 2 to 3 g/km 25 €/g

   If the transgression is over 3 g/km than the full punishment of 95€/g has to be paid. As from 2019 the entire rate of 95€/g per CO_2/km is coming due.

22 Own representation based on BMWi, 2012, p.14

23 Cf. BMWi, 2012, p.11

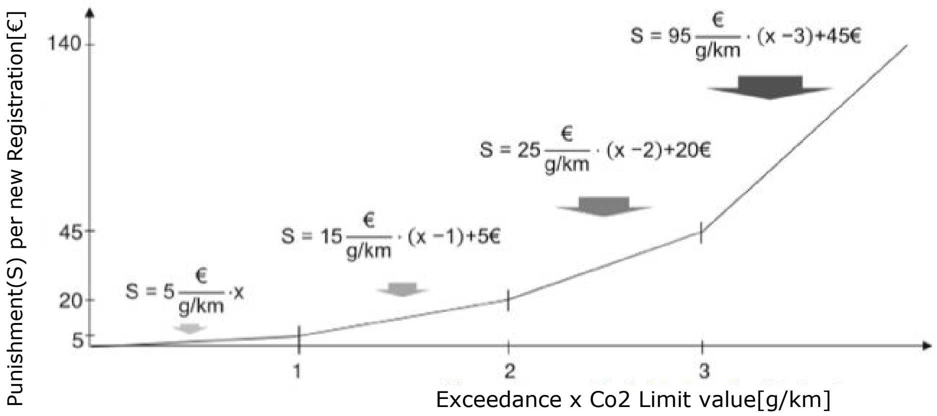

Figure 5: Calculation of penalty payment per new registration[24]

5. Furthermore, there will be a bonus for especially efficient vehicles. For each newly registered passenger car with an average of less than 50 g/km CO_2 emission a scaling will be adapted till 2016.

    a. – 3,5 vehicles for the year 2012

    b. – 3,5 vehicles for the year 2013

    c. – 2,5 vehicles for the year 2014

    d. – 1,5 vehicles for the year 2015

    e. – 1,0 vehicles from 2016 on [25]

Inherently this regulation was a positive step for the automobile industry as the planning certainty is given through such a regulation. This is extremely important for the manufacturers to invest in new research and development projects to improve the technology of the passenger cars. Whereas it has to be registered that there are no mandatory long-term targets after 2020 in order to maintain the intention of enhanced efficiency and climate protection.

24 Own representation based on BMWi, 2012, p.15

25 Cf. BMUB, 2009, p.2 ff

2.1.3 Regulation No. 333/2014

On March 11th 2014 the European Parliament and the Council have updated their regulation No. 443/2009, which was an important step for the automobile industry. In particular, the determined target value of 95 g CO_2/km, for the average emission of the passenger car fleet, for the period after 2020 should extend the planning horizon of the manufacturers in a positive sense.

Furthermore a preferential treatment for achieving the target of 95g CO_2/km was implemented in this regulation. This kind of bonus scheme is similarly in structure as the regulation No. 443/2009 EC. It proposes a favour in the CO_2 fleet-calculation for all new passenger cars with specific CO_2 emissions with less than 50g CO_2/km.[26]

Namely:

a. – 2,00 vehicles in the year 2020
b. – 1,67 vehicles in the year 2021
c. – 1,33 vehicles in the year 2022
d. – 1,00 vehicles in the year 2023

Additionally, the weighting factor was reduced to a value of 0,0333 by the year 2020. The factor determines the allowed emission surplus for heavier cars than the reference point.

From 2020:

Specific CO_2-Emissions = 95 + a × (M - M0)
Where we use:
M = mass of the vehicle in kilograms (kg)
M_0 = Will be announced in the end of 2014
a = 0,0333

The reference mass (M_0) will be proofed with respect to the average mass of the last three years and consequently adapted for the subsequent years. The verification will be conducted firstly in the end of 2014 and then every three years. The announced reference mass of 1372 kg does apply for the period of 2012 to 2015.[27]

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26 Cf. EU Parliament, 2009, p. L140/1

27 Cf. EU Commission, 2012, p.11 ff

2.2 Measuring of CO_2 emissions or fuel and energy consumption

During the year 1992, the European Union has extended their guideline 70/220/EEC by the emission and consumption regulation ECE R101. For the measurement of the CO_2 emissions and the consumption of fuel and energy the New European Driving Cycle (NEDC) is used. The Motor Vehicle Emission Group developed this cycle, which is a consultant council of the European Commission. As the graphic illustrates, the cycle is segmented in five phases. Four cycles are realised under city traffic and one in a non-urban environment.[28]

The entire test lasts approximately 20 minutes with a length of 11 kilometres. The average speed amounts 33 kilometres per hour included idle running phases. The high-speed level is confined with 120 km/h for this examination.

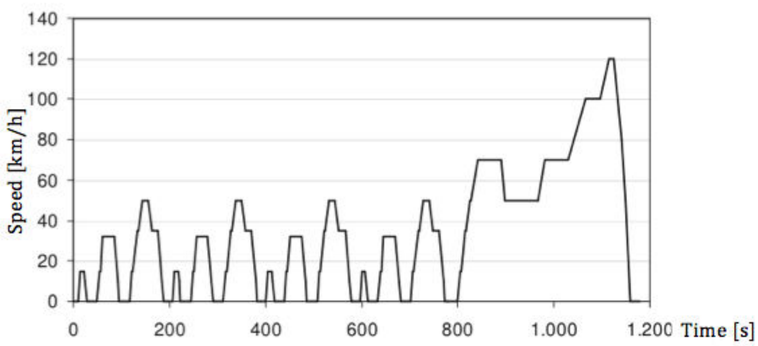

Figure 6: Speed profile of the new European driving cycle [29]

The compulsory parameters are defined with the ambient temperature, vehicle load capacity, cold start of the engine, switching points and the break of all loads. The entire cycle comprises acceleration-, lag-, constant- and idle phases.

The main criticism is that this cycle does not illustrate a realistic consumption in everyday life, neither the effective fuel consumption, in particular for hybrid vehicles. Analysis of this issue has demonstrated that different vehicle versions and various vehicle equipment play a decisive role in the results for CO_2 emissions and fuel consumption. Especially auxiliary equipment like air conditions plays a not insignificant role in this matter. As supplementary gears like audio systems, light and air conditions are not headed in the procedure for the approval of motor vehicles, the CO_2 emission

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28 Cf. BMWi, 2012, p.20

29 Own representation based on BMWi, 2012, p.20

results of the New European Driving Cycle are frequently by 15 to 20 per cent higher in the real traffic.

Additionally, the ECE-R101 regulation is criticised for the fact that battery electric vehicles and plug-in hybrid cars are not completely assessed, as the generation of energy is not calculated. Only under the pretext of renewable energy such cars are emission free in a proper way.[30]

Due to the fact of different driving cycles in important car producing countries like the United States or Japan, there is a common global test cycle planed. The so-called WLTP cycle (Worldwide Harmonized Light-Duty Vehicle Test Procedure) is scheduled to remove the New European Driving Cycle in 2020. That would be an important step for all car manufacturers as the different measuring methods often lead to extremely high costs of car development in order to stay competitive to the peer group.[31] In addition, a worldwide standardized cycle, would lead to much better transparency for customers as well as manufacturers themselves.

2.3 Pattern of the automobile industry

As this paper is later mainly concerned with the progress of the automobile industry on the financial markets, particularly with the influence of the improvement of CO_2 emissions, the pattern of this industry should be considered closer.

The automobile industry is one of the major and most influential industries worldwide. According to the world automotive association OICA (The international organisation of motor vehicle manufacturers) the automobile branch builds 60 million vehicles a year. Therefore a workforce of about 9 million is required directly and approximately 40 million people are employed with indirect jobs in the community. In total this leads to an incredible rate of more than 5 per cent of the total manufacturing employment in the world.

Furthermore, with over 84€ billion in research, development and production the branch is regarded as a main innovator. Like in the history of the technology the car industry is an important player for the society and other industries. Not least because it generates over €400 billion on government revenues due to vehicle manufacturing, the industry is vitally important in modern times.[32]

30 Cf. BMWi, 2012, p.20

31 Cf. Puls, 2013, p.19

32 Cf. OICA, 2012, Last accessed: 22.5.2015

The European Union is a major player in the worldwide automobile production. With a share of around 23 per cent in 2014 the industry is stronger than the NAFTA (North American Free Trade Agreement) with approximately 21 per cent. The driving force with 47,4 per cent is the Asian market.[33]

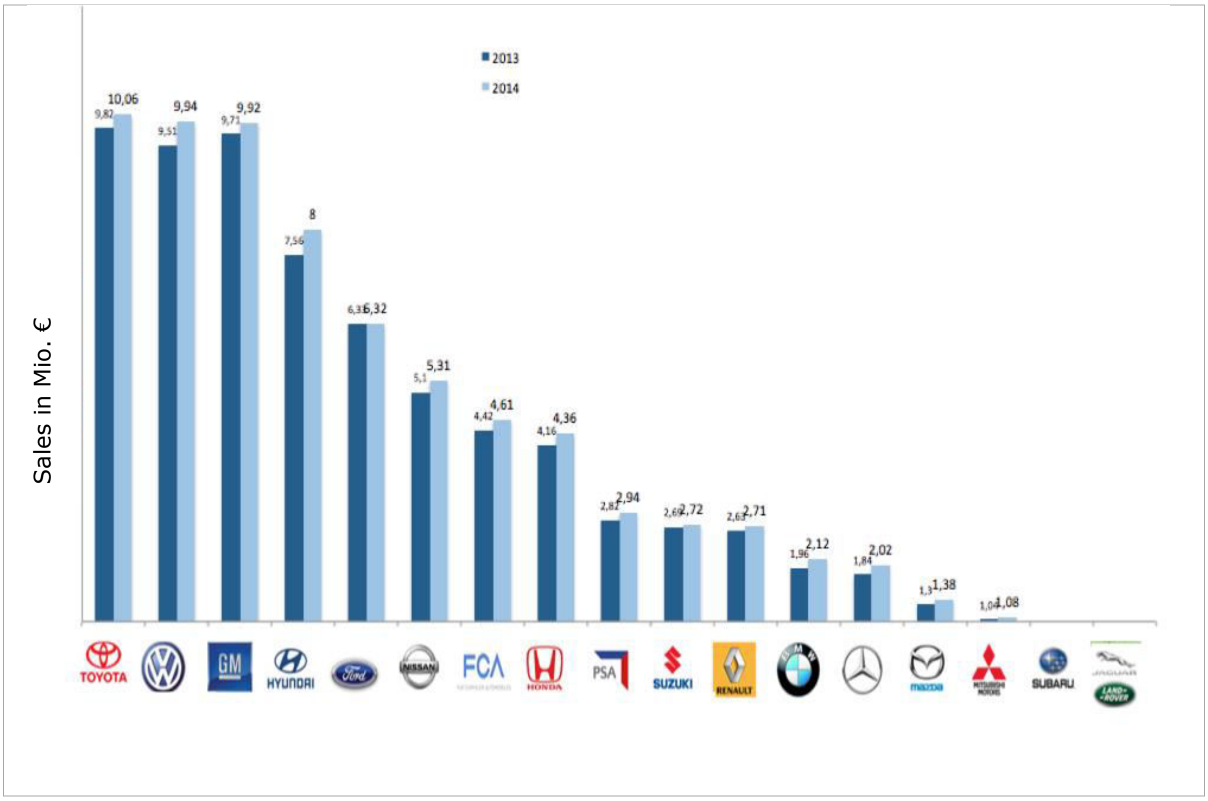

Figure 7: Sales in Mio. per car manufacturer in 2013 and 2014[34]

Even though there are many minor manufacturers in this industry, the branch is mainly characterized by huge concerns, which are mainly responsible for most of the trends and developments. In the figure above it is evident that the three major manufacturers are distributed in the worlds biggest economic areas Japan, Europe and United States. With just around 10 millions of sold cars Toyota, Volkswagen and General Motors are on top of the worldwide sales.

33 Cf. Statista, 2016c, Last accessed: 15.10.2015

34 Own representation based on CAM, 2015, Last accessed: 17.10.2015

2.4 Innovations in the car industry

For generations the automobile industry is known for their driving force regarding industrial development. It started with the evolution of the assembly line work by Henry Ford, followed by "just-in-time-production" or the "Kanaban" method by Taiichi Ohno, just to have some examples.

In relation to this paper, the innovation auf the automobile industry is getting evermore important due to the strict regulations of CO_2 emissions. That is why technological improvements are absolutely essential to stay competitive. The subsequent graph shows the most innovative manufacturers. With Volkswagen, Daimler and BMW under the best four automobile groups the Germans occupy a very dominant position. This ranking could be very interesting to observe in the future, as the above mentioned are currently characterized with high emission values.

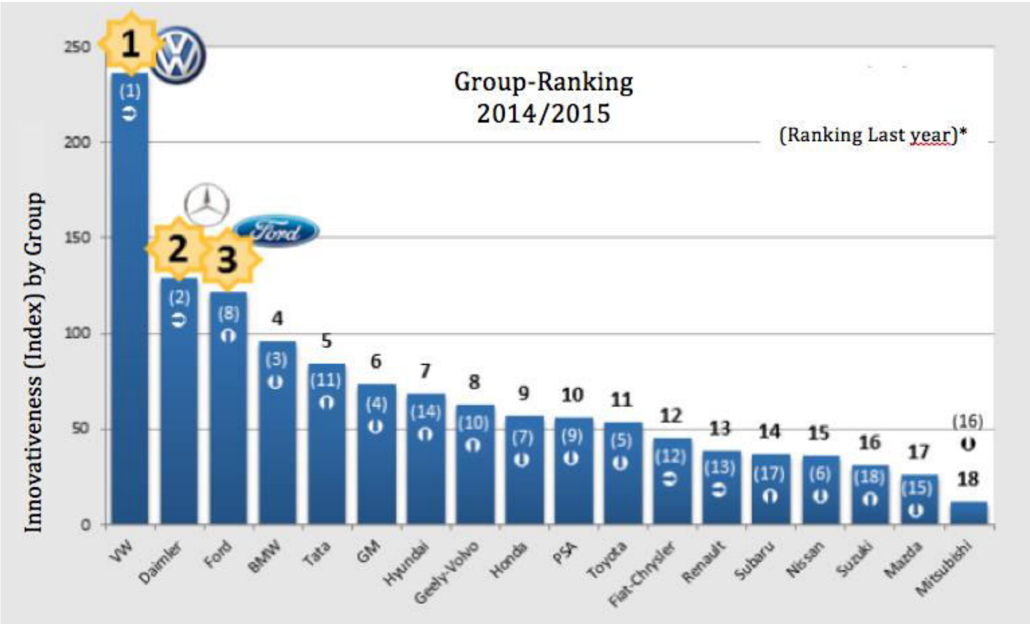

Figure 8: Innovativeness per car manufacturer in 2014/2015[35]

35 Own representation based on CAM, 2015, Last accessed: 17.10.2015

2.4.1 Development and production cycle on vehicle and technology base

The following section aims of an understanding of the purpose of the current development and production cycle in the automobile industry. Due to this examination it should be demonstrated how long the phasing-in period lasts under the presently given stage of technological development. Therefore the process of the automotive development will be analysed.[36]

At the beginning the focus is geared to the lifecycle of a technology. Therefore a plenty of different models are available to describe the typical process of a technological development over time. In this paper the model of Arthur D. Little will be considered particularly. This model for the development of a technology life cycle is classified in four stages: The emergence-, growth-, maturity- and seniority phase.[37]

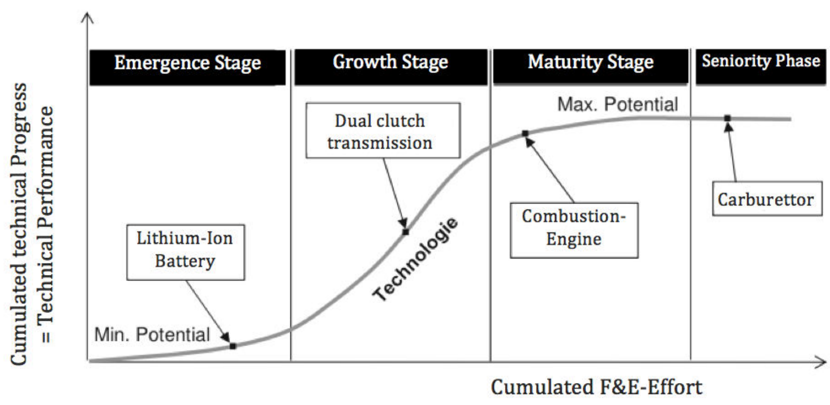

Figure 9: Technology Cycle; S-Curve [38]

2.4.1.1 Emergence phase

At the beginning of a new technology, there are a plenty of problems to be solved. During this development stage the technology has a very low level of awareness and thus often slightly equipped with research funds. Furthermore, in this crucial phase of emergence many technical problems occur which in turn leads to a weak rate of technological process. An example therefore is the lithium-ion battery for mobile applications, which was not able to exceed its minimal potential yet. Finally it should

36 Cf. Mock, 2010, p.10

37 Cf. Mock, 2010, p.10 ff

38 Own representation based on BMWi, 2012, p.36, Last accessed: 17.10.2015

be pointed out, that there are often major problems of acceptance and enforcement due to social, political and also economical reasons.[39]

2.4.1.2 Growth phase

Due to continuously and persevering efforts of the developing team it is sometimes possible to maintain the next stage and outpace the tougher initial phase. To achieve this stage is one of the most important progresses in a development division as it is the phase where the growth begins to accelerate. Reasons for such a breakthrough can be the solving of a huge technical problem or just the invention of a leading standard. An example for this phase is the dual clutch transmission, which is a strongly growing technology at the moment.

Usually the process accelerates quickly after such a technology is becoming known in the public. Thereby the incentives are raised from different bodies like universities or companies and by the way the first products are getting sold on the market.

2.4.1.3 Maturity phase

If the maturity phase is reached, the rate of technological development is slowing down rapidly. The focus is shifting from product innovation to process innovation. At that stage a point is reached where the further progress is only possible under huge financial and time-consuming effort. Mostly this supplementary effort is in no relation to the additional success and therefore the innovation progress decelerates. With regard to the automobile industry in particular, the combustion engine is an excellent example as it has nearly reached its maximum potential.[40]

2.4.1.4 Seniority phase

When the maturity stage is accomplished, new stimuli are needed in order to attain new proceedings. Therefore drastic changes are necessary to renew the technological structure. Finally, a new technology replaces the old one and the product life cycle repeats from the beginning. [41]

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39 Cf. Mock, 2010, p.11

40 Cf. BMWi, 2012, p.37

41 Cf. Mock, 2010, p.11

2.4.2 Cycles of the car development

After a more theoretical introduction regarding the life cycle of innovations and developments, the next part should be more precise concerning the implementation time of manufacturers products. For the producers it is very important to have a specific planning horizon in order to research and develop new technologies. Especially in times like these, when the market participants are facing new regulations in increasingly shorter periods. To avoid financial penalties and mainly to stay competitive the manufacturers are forced to develop and produce very quickly.

In a next step, the focus is geared to a complete overview of the activities related to the vehicle development and the appropriate technologies. Principally the time axis of the development chain can be divided into three stages until the start of production (SOP) is reached. Of course it is important to clarify that the indicated time periods of the development stages are reference values on average. Obviously, there are many improvements and innovations that are implemented more quickly than others.

[42] As the following illustration shows the most time consuming stage is the research period, which is generally estimated between five and ten years. Afterwards the advanced development phase should be finished within three to five years. Finally the series development is expected to last for two to five years, dependent on the extent of the realised project.

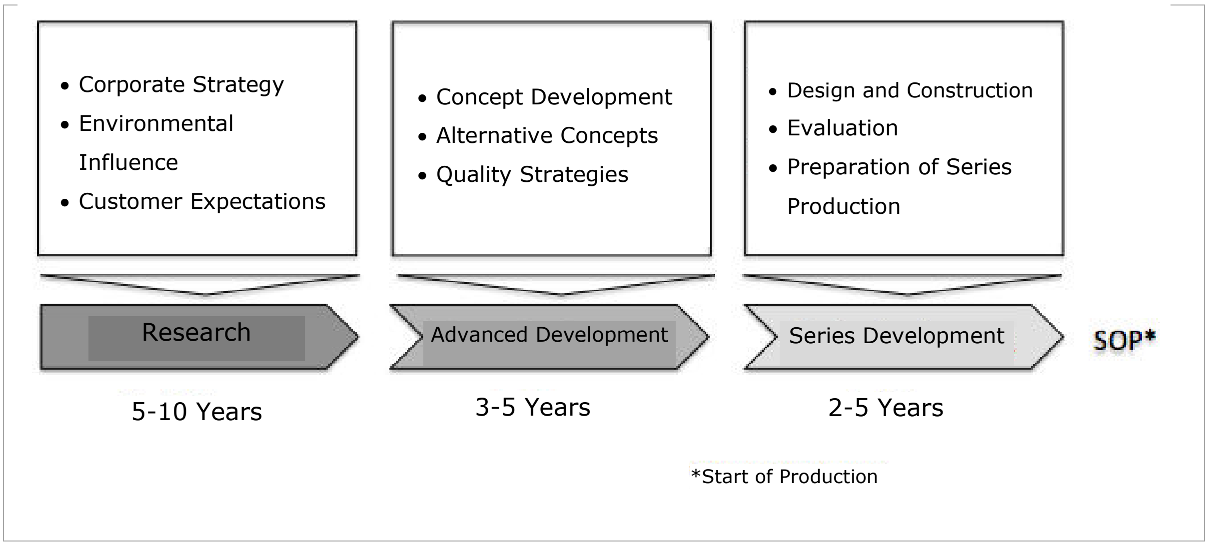

Figure 10: Stages of car development [43]

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42 Cf. BMWI, 2012, p.38

43 Own representation based on BMWi, 2012, p.37, Last accessed: 17.10.2015

As mentioned before the time intervals for new automobile models and technologies are shortening. Therefore a closer look into some practical examples in various vehicle segments will help to support this thesis. Considering the historical product cycles right up to the current automobile models, a clear tendency toward shorter cycles in the whole industry is visible. Nevertheless, it should be pointed out that such a development cycle is a very time-consuming process and therefore an extremely sensitive issue for the politics as well as the directly affected car manufacturers who are forced to implement the defined limits as fast as possible.

The following illustration shows the time line from 1970 down to the present day, with respect to the three segments, namely the compact class, the middle class and the premium class.

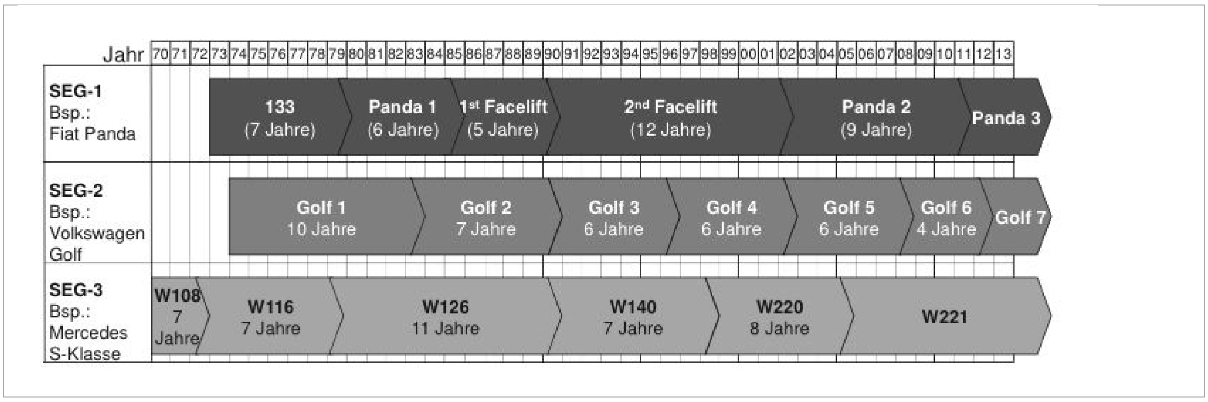

Figure 11: Examples of shortening product cycles [44]

On the basis of the Volkswagen Golf it is well comprehensible. Whereas the Golf 1 was produced for more than ten years, the Golf VI replaced the Golf V after six years. Admittedly, the Golf VI and the Golf V had the same basic structure and can be clarified as a huge facelift. That is why the Golf VI was substituted after only four years due the Golf VII. On the one hand there are the decreasing intervals between new product cycles due to the competition in the market and the changing customer requirements. Especially in Europe the middle class is very popular and therefore highly competitive. On the other hand the manufacturers are forced by the government regulations, like the CO_2 limits, to be able to react quickly on market changes. [45] As a result the very tight deadlines imposed by the legislators will always be derived from the present stage of technology.

44 BMWi, 2012, p.39, Last accessed: 17.10.2015

45 Cf. BMWi, 2012, p.39

2.5 Alternatives: electric cars

One of the most current subjects in the automobile industry is the question, whether the electronically operated cars will prevail against combustion vehicles during the next years. Specifically in times like these, when one CO_2 emission regulation is followed by another, the electronically alternative is in strong demand. In this context it is often to be said that battery electric cars are emission free vehicles. Indeed, from a scientific view it should be contemplated more accurate and therefore the whole process of emergence will be observed.

In the following section a comparison of CO_2 emissions emergence will be conducted between:

1. Battery electric vehicles, and
2. Comparable passenger cars with conventional combustion engines

Most of the analysis between the classic technology of vehicles and the emerging electrically powered cars are realised in a contemplation of just one parameter. In particular, this is the "tank-to-wheel" emission for the combustion cars and the "plug-to-wheel" emission for the battery-operated vehicles.[46]

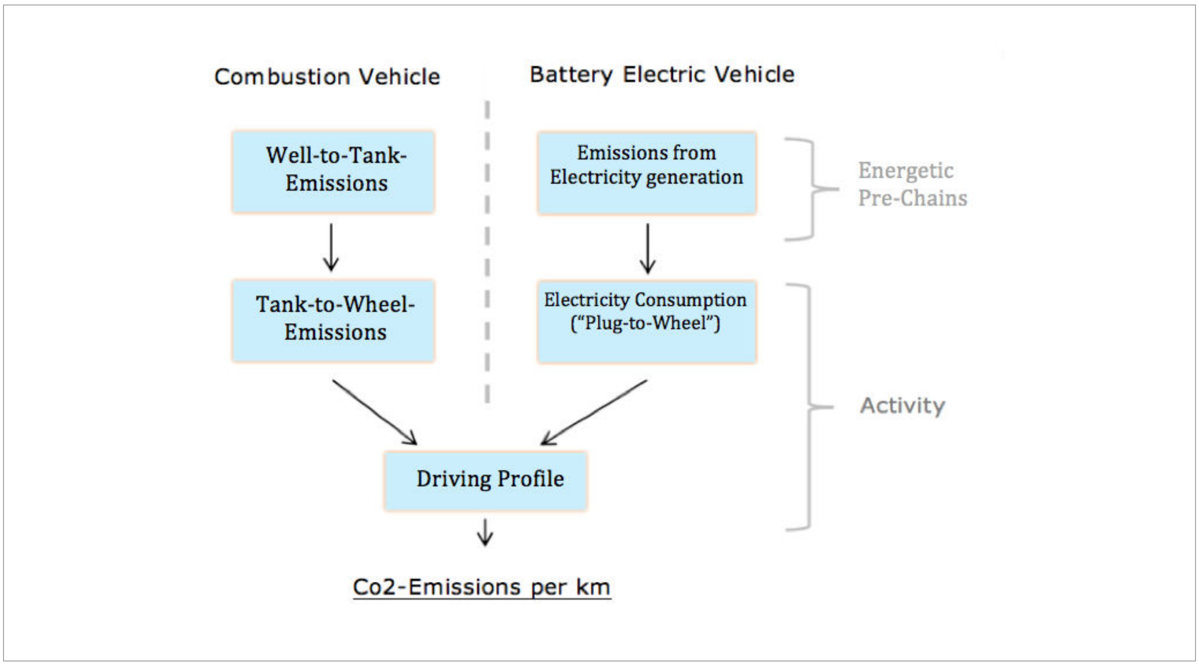

Figure 12: Parameters of the CO_2 Emission comparison [47]

46 Cf. Wellbrock, Fette, Gabriel, Janßen, 2011, p.15

47 Own representation based on Wellbrock, Fette, Gabriel, Janßen, 2011, p.15, Last accessed: 17.10.2015

This implies that just the final consumption and in further consequence its emission is considered. That is the reason why electric cars are commonly denoted as "zero-emission" vehicles, which is not entirely right. Even though nearly all manufacturers information are announced from this single aspect, it should be prudent that there is also a precursor of CO_2 generation.

Particularly there are two steps of emission that should be observed accurately. Regarding the combustion vehicles, the first step is determined by the so-called "Well-to-Tank" emission. Specifically this is the output that is generated due to the production and provision of fuel. The second part of the existing parameters is the mostly known "Tank-to-Wheel" emission, which occurs during the journey when the fuel is getting combusted. In order to compare these two modes of driving the whole chain of emission should be contemplated to obtain a rational assessment.

In contrast to the combustion vehicles, there is also a pre-stage of emission generation for battery electric vehicles, namely the produced emission due to the generation of electricity. In addition, the "Plug-to-Wheel" consumption, which is mostly donated as "zero-consumption", has to be involved. But, even this "clean section" of consumption is in a narrow sense not completely emission free, as the loss of load of the gross quantity, which is required for one kilometre per trip, has to be considered.[48]

For a more deliberated reflection regarding the oblique emission of electric cars, the electricity generation has to be examined. Principally, the supply during the operation of the car constitutes a decisive role. According to reports by McKay and Helmers an average consumption of 15 kWh/ 100km was assumed in the market. A further influencing variable is the sort of electricity, which is used for the process. Calculated according to the conventional power plant mix that is quoted with 600g CO_2 /kWh, it leads to an output of 90g CO_2/kWh. Indeed, the operation of electric cars with energy from coal or lignite, which are dedicated to the most polluting sources of supply, would result in a cleaner task of mobility.[49] This calculation shows clearly that the emissions of battery electric vehicles are obvious under the output generated by conventional vehicles, even though the term "zero-emission" is not durable from an entire perception.

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48 Cf. Wellbrock, Fette, Gabriel, Janßen, 2011, p.15

49 Cf. Helmers, 2010, p.573

Nowadays there are useful ways of studies between battery electric vehicles and conventional vehicles available. This was not always the case as the life cycle assessments were conducted with the enormous energy consuming cars from 1990 in comparison with the current very low combustion engines.[50]

Certainly, in my point of view the market share for electric vehicles is currently too small to be relevant for the current discussion and is therefore not further included in this paper. The reason why it is introduced in this section is naturally the perceived importance of this niche for the near future. Further investigations in this field should definitely carry out a comparison between conventional and electrically operated vehicles based on standardized and the latest state-of-the-art technolgy .

50 Cf. Helmers, 2010, p.573

3. Practical Part

The following part presents an empirical analysis of the observed trends in CO_2 emissions for seven large car manufacturers. After an explanation of the data used, the second section presents a description of how CO_2 emissions evolved over time in view of increasingly stricter standards imposed by EU regulation. Particularly, I will test whether the Bass Diffusion model, which was introduced as model of innovation diffusion, can be usefully applied as the "law of motion" for the introduction of lower emission engines in the car industry. The third section presents an empirical analysis with a view to testing whether and how the car manufacturers' efforts to lower the CO_2 emission level impacted on their stock prices.

A car manufacturer's stock price is determined by a number of factors such as profitability, the evolution of market shares etc. Although CO_2 emissions are not likely to be *the* main factor, their importance as an explanatory variable for the share price should not be underestimated. The "Volkswagen" affair is testimony of this link, as their stock price was plummeting considerably after the distortion was revealed. In this context, it can be assumed that the ability to reduce emission values is closely connected to the general innovative capacity of a company for which reason they may be a proxy for the future earnings capacity and, hence, the stock market value. Emission values may also give an indication of a company's ability to react swiftly to new regulations, for example those imposed by the European Union, and can therefore be used to compare the competitiveness of various car suppliers.

Consequently the examination has been analysed for various correlations and conspicuous features during some crucial points in time during the investigated period. Finally, the investigation will be analysed under various standpoints in order to achieve some developments regarding the automobile industry and its stock prices.

3.1 Data

The two main data for the investigation of the correlation and repercussions of the study are the car manufacturers stock prices and the CO_2 emissions. The procedure for the various car manufacturers stock prices was dependent on their primary exchange, which is mostly the spot with the highest revenue for the respective stocks. For example the stock prices of the Ford Motor Co. have been applied from their home market, which is the New York Stock Exchange. In comparison, the Volkswagen data have been requested from the electronic trading platform Xetra, located in Frankfurt. The investigation period was from the beginning of 2007 till the end of 2013 and the stock prices used, were on a monthly basis. As a reason for the starting year in 2007, the official EU announcement can be mentioned, which will provide a crucial approach in the adjustment of the car manufacturers CO_2 emissions behaviour. The reference place of the data was the online database of yahoo finance.

Regarding the CO_2 emissions, the university of Vienna provided the dataset for the examination. In a first task it was necessary to screen the particular car manufacturer groups, concerning their members beyond the period in question. Afterwards the respective shares of the group members had to be determined in order to break down the existing CO_2 emission data. Therefore the annual reports of the groups have been used to provide the distribution key. The allocation was conducted due to the number of sold cars of the various car manufacturers. Unfortunately it was not possible to obtain detailed information by the car manufacturers directly, regarding the accurately number for each car model or respectively their motorization. Due to this data it would have been possible to obtain very detailed values of the emission levels. However, if the entire computation is considered the values of the weighted shares of the group members are leading to realistic CO_2 emissions in comparison to other studies and authorities, like the European Environment Agency (EEA). The following figure illustrates the calculation procedure:

VW Group				
2007	**Sales (tsd.)**	**Group-Share**	**Co2 g/km**	**weighted Co2**
VW	3664	0,622	189	117,472
Audi	1200	0,204	201	40,916
Skoda	620	0,105	182	19,142
Seat	411	0,070	151	10,528
Total	5895	1,000	180,75	**188,057**
2008	**Sales (tsd.)**	**Group-Share**	**Co2 g/km**	**weighted Co2**
VW	3648	0,616	176	108,381
Audi	1275	0,215	190	40,893
Skoda	626	0,106	170	17,964
Seat	375	0,063	135	8,546
Total	5924	1,000	167,75	**175,784**
2009	**Sales (tsd.)**	**Group-Share**	**Co2 g/km**	**weighted Co2**
VW	3459	0,627	161	101,016
Audi	1183	0,215	187	40,127
Skoda	552	0,100	162	16,221
Seat	319	0,058	125	7,233
Total	5513	1,000	158,75	**164,596**
2010	**Sales (tsd.)**	**Group-Share**	**Co2 g/km**	**weighted Co2**
VW	3.863	0,631	157,000	99,132
Audi	1.321	0,216	187,000	40,377
Skoda	585	0,096	155,000	14,821
Seat	349	0,057	119,000	6,788
Total	6.118	1,000	154,500	**161,119**
2011	**Sales (tsd.)**	**Group-Share**	**Co2 g/km**	**weighted Co2**
VW	4.450	0,632	154	97,275
Audi	1.543	0,219	179	39,205
Skoda	690	0,098	155	15,181
Seat	362	0,051	115	5,909
Total	7.045	1,000	150,75	**157,569**
2012	**Sales (tsd.)**	**Group-Share**	**Co2 g/km**	**weighted Co2**
VW	4.850	0,664	147	97,598
Audi	1.299	0,178	166	29,519
Skoda	727	0,100	144	14,331
Seat	429	0,059	102	5,990
Total	7.305	1,000	139,75	**147,437**
2013	**Sales (tsd.)**	**Group-Share**	**Co2 g/km**	**weighted Co2**
VW	4.704	0,651	145	94,327
Audi	1.349	0,187	167	31,155
Skoda	719	0,099	138	13,722
Seat	459	0,063	111	7,046
Total	7.231	1,000	140,25	**146,250**

Table 1: Calculation of the group value for Volkswagen

- *The first column shows the various brands, which belong to the Volkswagen group. Regarding the VW group we have VW, Audi, Skoda and Seat.*
- *The second column displays the sold cars in thousand, followed by the share in per cent of the whole group.*
- *The column "Co2 g/km" indicates the emission values in gram per kilometre; therefore I calculated the average emission value per year for all models of the particular car brand from the data set.*
- *The column "weighted* CO_2*" is the result of the share in per cent times the* CO_2 *value in g/km.*

Initially, an entire overview of all investigated automobile manufacturers and their CO_2 values should provide a better understanding for the situation. It is not surprisingly that heavy motor vehicles are leading the table and are simultaneously forced to lower their values most strongly. As the figure shows, Daimler, BMW and Volkswagen are located in the upper part of the figure. Due to the fact that there were no tangible consequences for high CO_2 emissions in the past, car manufacturers had no incentives to invest in emission-decreasing technologies.

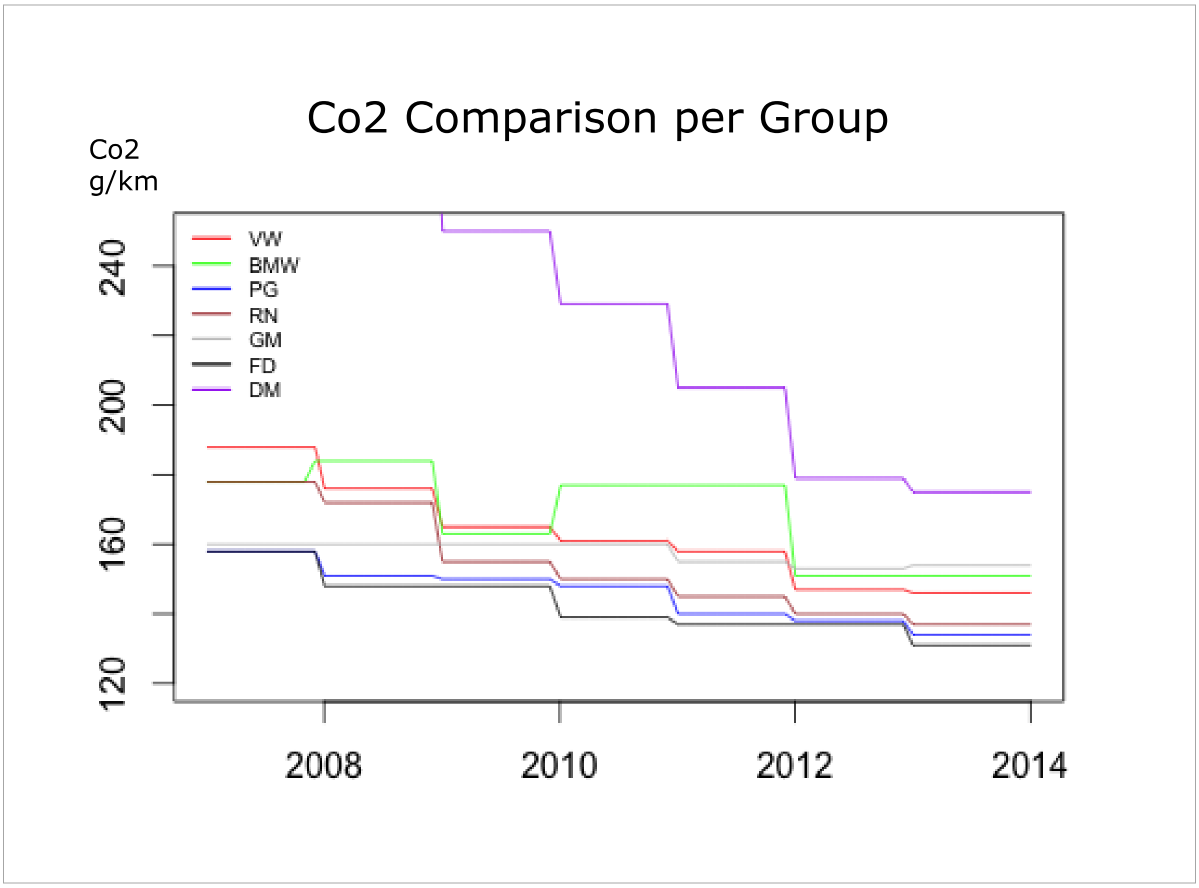


Figure 13: CO_2 emission values per group

In the next step, the CO_2 emission values and stock price data for each car manufacturer are represented explicitly. The graphical representation has been scaled down in order to achieve a useful display of the stock price and the CO_2 emission. As the two particular values are sometimes completely different data, it would not be possible to constitute the illustration in a real scale. The red line, which indicates the CO_2 value, constitutes a staggered presentation due to the values on a yearly basis.

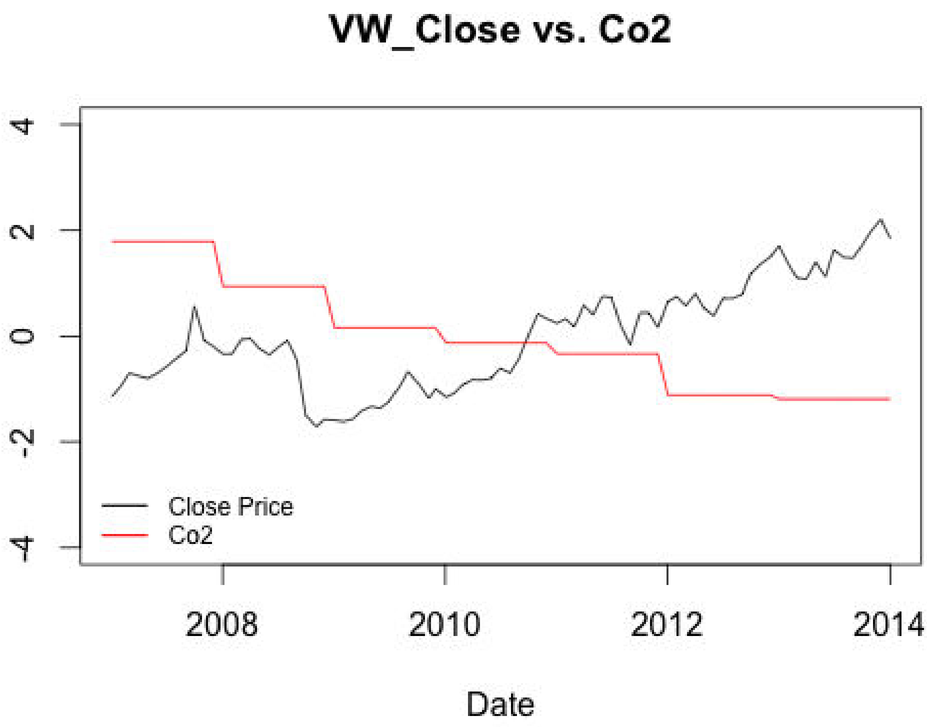


Figure 14: VW Stock Price in contrast to CO_2 Emission(g/km)

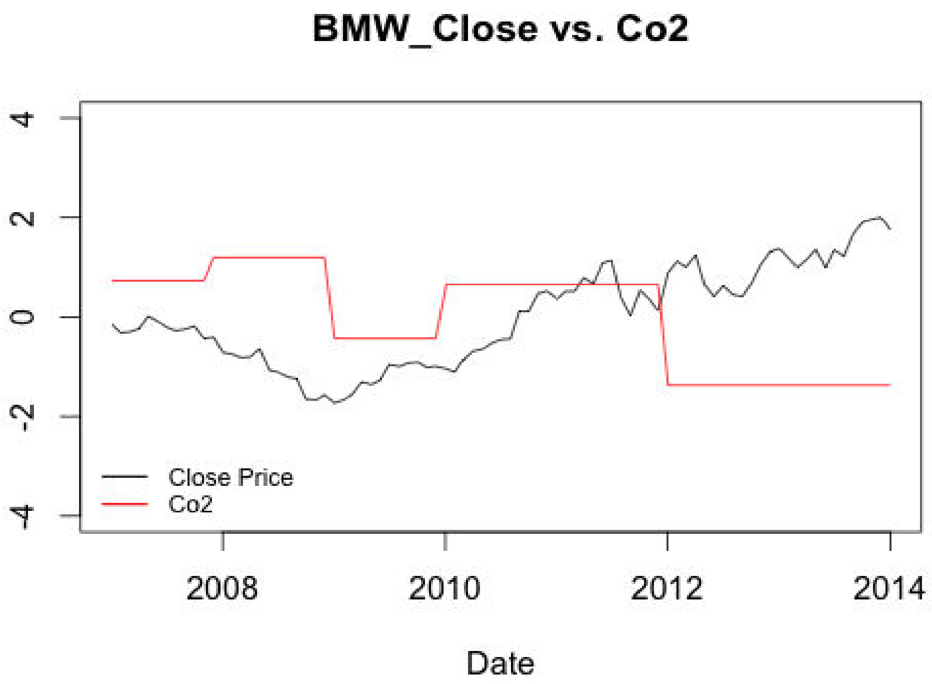


Figure 15: BMW Stock Price in contrast to CO_2 Emission(g/km)

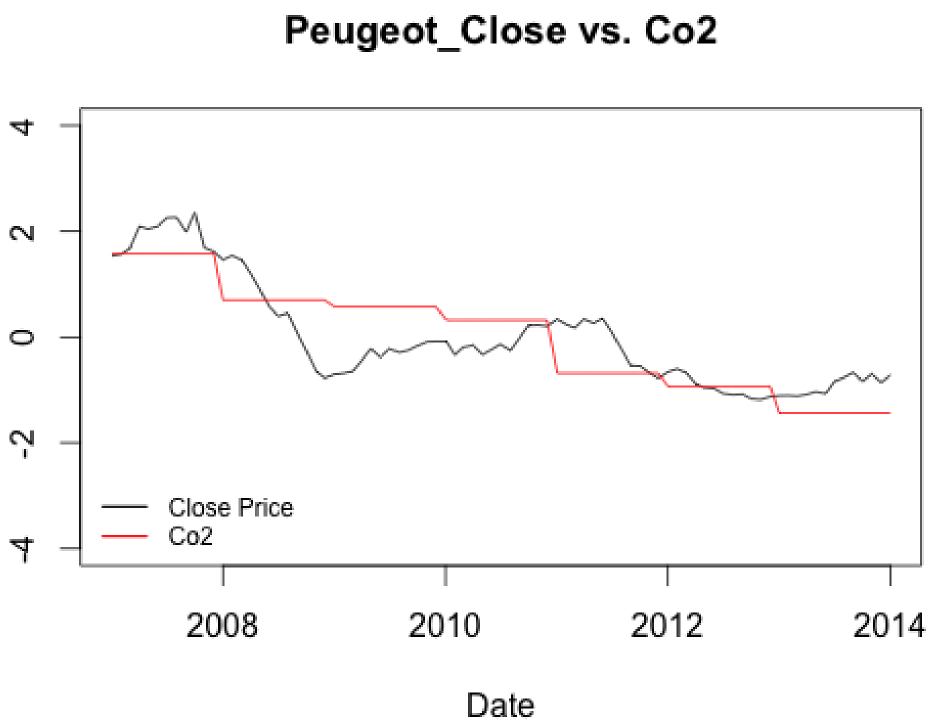


Figure 16: Peugeot Stock Price in contrast to CO_2 Emission(g/km)

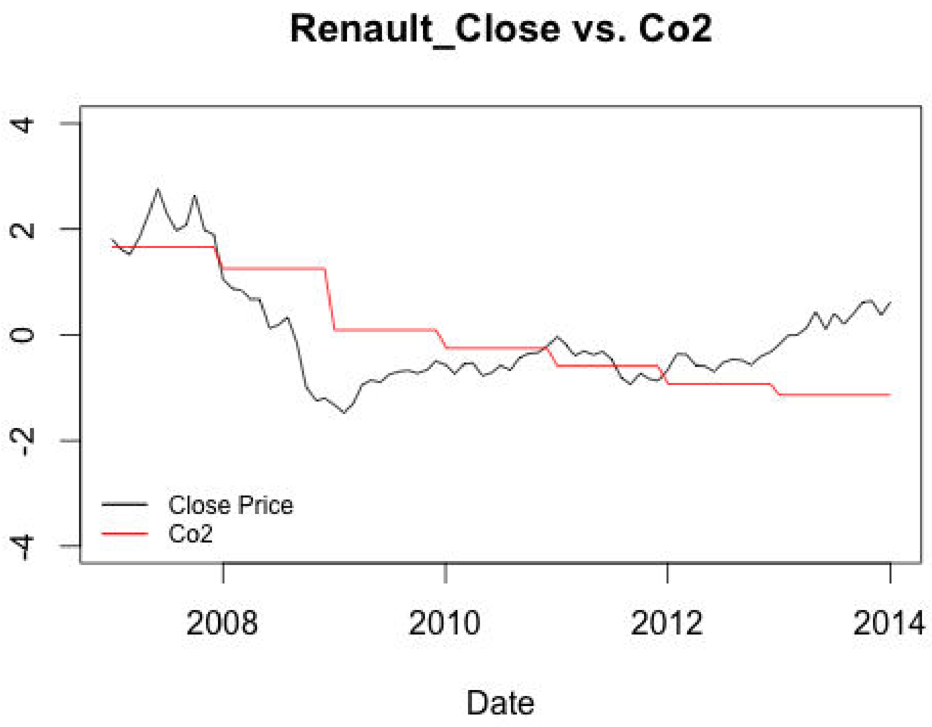


Figure 17: Renault Stock Price in contrast to CO_2 Emission(g/km)

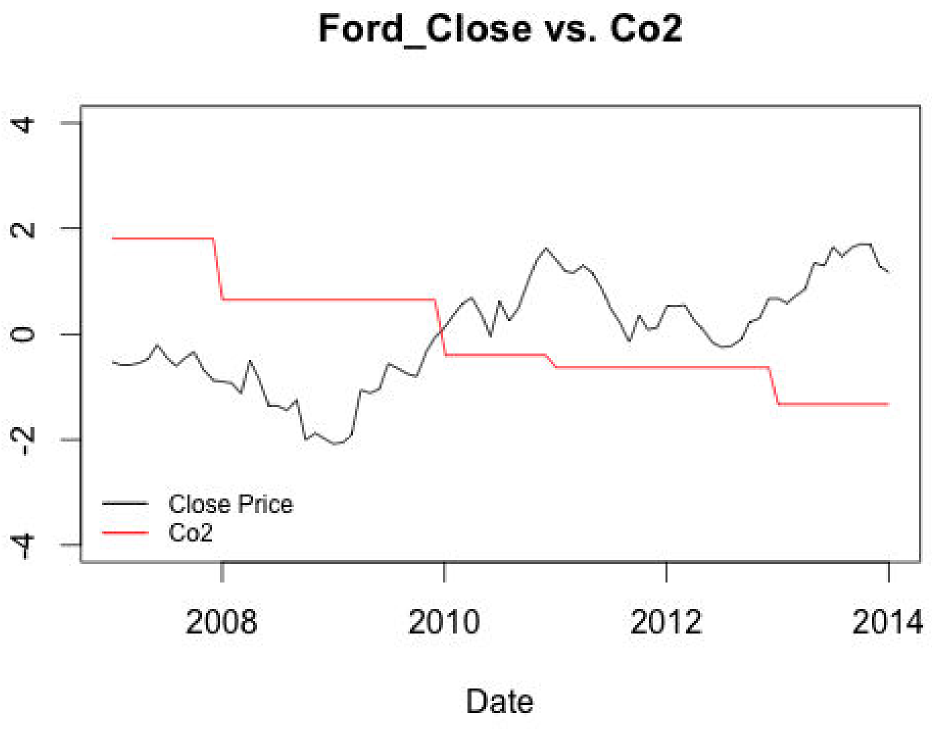


Figure 18: Ford Stock Price in contrast to CO_2 Emission(g/km)

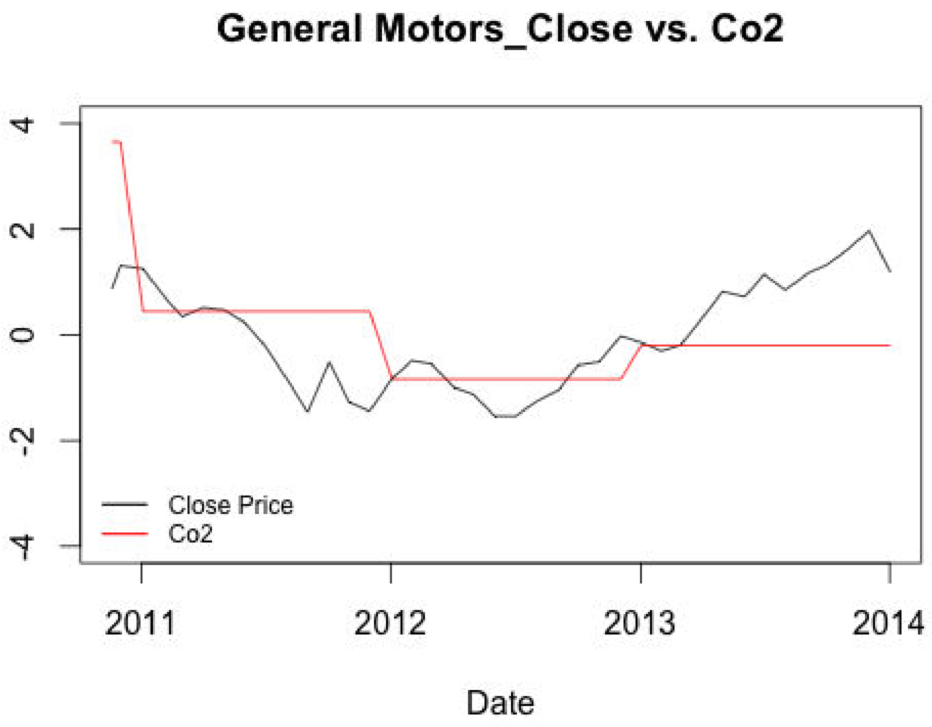


Figure 19: General Motors Stock Price in contrast to CO_2 Emission(g/km)

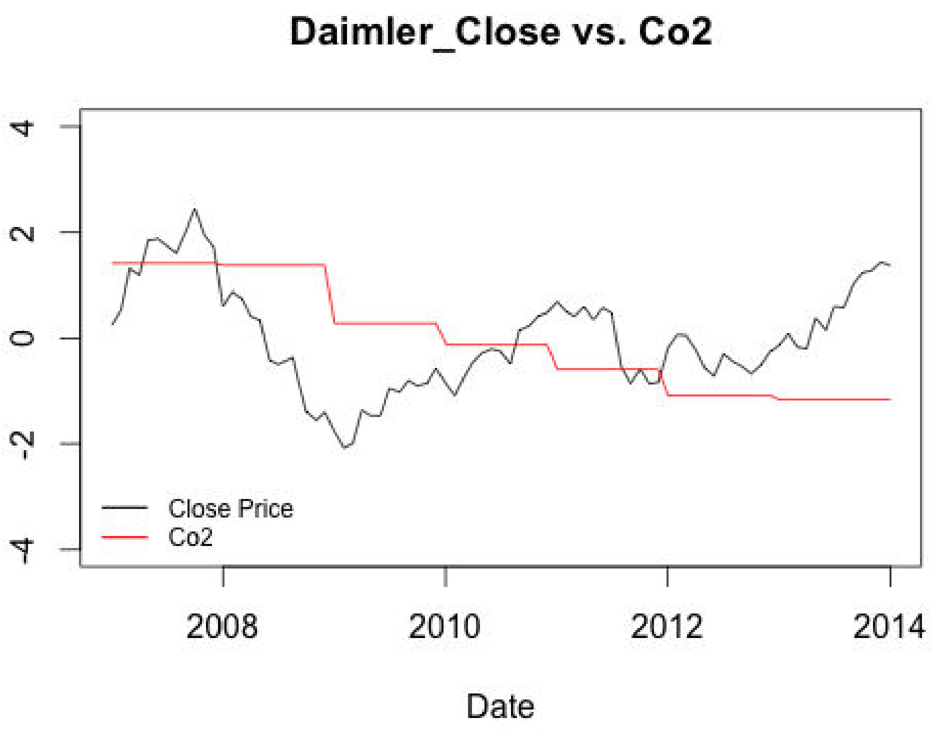


Figure 20: Daimler Stock Price in contrast to CO_2 Emission(g/km)

3.2 The evolution of CO_2 emissions as a diffusion process

In this section the adjustment of CO_2 emissions in reaction to stricter EU-wide regulations will be investigated. For this approach I used a diffusion model, which is often used to describe processes that are triggered due to the introduction of new innovations into a market. In general, such diffusion models are trying to explain growth and saturation processes and are assuming that the analysed time series will approach a saturation limit in the long term.

In particular, the Bass-Diffusion-Model was developed to investigate how the process of new products and innovations are implemented in a market by Frank Bass. In 1969, Frank Bass established a simple differential equation, which enables to assess the market participants by their speed and timing of adoption.[51] As this paper is concerned with the adaption of the new legal regulations in order to achieve the required limit values, I implemented the internal influence diffusion model, which has initial been employed to model the contagion of new products and innovations.[52] Rogers (2003) described such a process as the diffusion curve, an S-shaped cumulative distribution curve.[53]

Mathematically, the equation is described by Mahajan and Peterson due their internal influence diffusion model[54]:

$$N(t) = N/1 + \frac{(N - N_0)}{N_0} * \exp[-B * N * (t - t_o)]$$

The adjustment process is described by the following differential equation:

$$\Delta E_{i,t} = E_{i,t} * (E_{i,t} - N) * B_i$$

[51] Cf. Bass, 1969, p.215 ff

[52] Cf. Boushey, 2012, p.132

53 Cf. Rogers, 2003, p.243 ff

54 Cf. Boushey, 2012, p.133

The change in the emission level for car brand i at any point in time is dependent on:

Ei, t … the current emission level

Ei, t - N … gap between the current emission level and the technological/regulatory threshold

Bi, … effort with which individual car maker closes the gap between the current emission level and the technological/regulatory threshold

The equation can be interpreted in the following way: The higher the current emission level the easier it will be for a car maker to lower the emission level by adopting already existing technology. Furthermore, the higher the gap between the current emission level and the technological/regulatory threshold the more effort the car maker will have to make in order to lower the emission level at any point in time. Since the effort individual car makers will make to close this gap will differ we multiply the second term with the effort parameter B(i), i.e. the higher this parameter the faster the car maker will converge towards the technological/regulatory threshold.

Solving the differential equation results in the following equation:

$$E_{i,t} = N / \{1 + [(N - E_{i},0) / E_{i},0] * exp(-B_{i} * N * t)\}$$

Since an individual car maker's effort parameter B_i is unknown, it needs to be estimated by an appropriate statistical method.

That is why the equation is a suitable model for this specific case of CO_2 emission reduction. This model should be able to give a suggestion, which car manufacturer is most capable to reach the given CO_2 targets.

First I tried to estimate the Bass-Diffusion model with a non-linear-regression procedure provided by the statistical software R, but due the very small sample size I could not obtain meaningful results due to convergence problems. As an alternative I used a heuristic method in terms of the Excel Solver, which brought some plausible results. I applied the method of least square estimator with the excel solver to estimate the saturation limit N, the starting value A and the growth factor B.

In a first attempt I made no restrictions to the model, which resulted in some extreme results. In particular, I obtained (non-sensical) negative values for N in the case of BMW and Daimler. In order to overcome this problem, I estimated the saturation limit by using the pooled data set for all car suppliers under investigation. The estimated value for this parameter was 67g CO_2 per kilometre. This seems a realistic value that could be reached in the near future. For this reason, I found it useful to compare the different car manufacturers in their speed and ability to achieve the estimated value for the entire industry.

Table 2: Results with no restrictions to N

	VW	BMW	PG	RN	GM	Ford	Daimler
N	123	-923	-4	118	130	120	-1108
A	188	183	158	179	185	157	320
B	0,00107	0,00003	0,00018	0,00132	0,00098	0,00126	0,00008
RES	16,38	708,16	76,39	26,24	35,44	498,61	22,62

Table 3: N restricted to 67

	VW	BMW	PG	RN	GM	Ford	Daimler
N	67	67	67	67	67	67	67
A	186	183	158	177	183	156	324
B	0,00044	0,00026	0,00033	0,00054	0,00035	0,00038	0,00060
RES	35,81	515,50	17,39	51,30	85,64	27,73	1036,60

Table 4: B-Value (growth factors)

N=67		N=unrestricted	
Daimler	0,00060	RN	0,00132
RN	0,00054	Ford	0,00126
VW	0,00044	VW	0,00107
Ford	0,00038	GM	0,00098
GM	0,00035	PG	0,00018
PG	0,00033	Daimler	0,00008
BMW	0,00026	BMW	0,00003

As we can observe in table 4, Daimler has reached the highest growth factor (B), which indicates the fastest adaption of lower emissions in the future in relation to the common threshold of 67g CO_2. As mentioned before this result clearly makes sense as the starting emission value of 324g CO_2 of Daimler is extremely high, it is easier for this group to lower its levels by adopting prevailing technology. Thus, Daimler is able to reach a higher B-Value in contrast to the peer group. Regarding the manufacturers with starting values of around 180g CO_2, which apply to General Motors, Renault, Volkswagen and BMW, one can spot ambitious emergence of adoption in particular for Renault and also Volkswagen, whereas General Motors and especially BMW show fairly weak values. Ford and Peugeot are leading the table of CO_2 values in 2007. The reason why they are positioned in the upper part of the growth values table, can be explained as their innovation potential is limited due to their advanced current values in contrast to the reference group.

The subsequent plots show the growth curves of the individual car manufacturers from 2007 to 2050. The steeper the curve proceeds the faster is the development of the improvement in CO_2 reductions. Of course the starting value assumes an important role in the speed of enhancement.

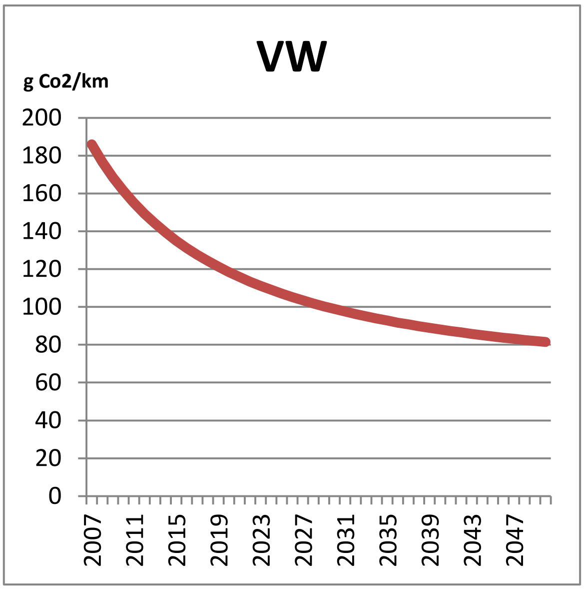


Figure 21: VW Diffusion Curve

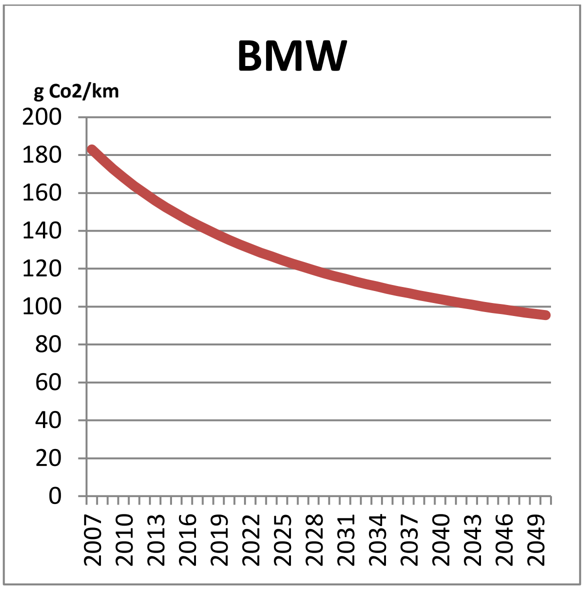
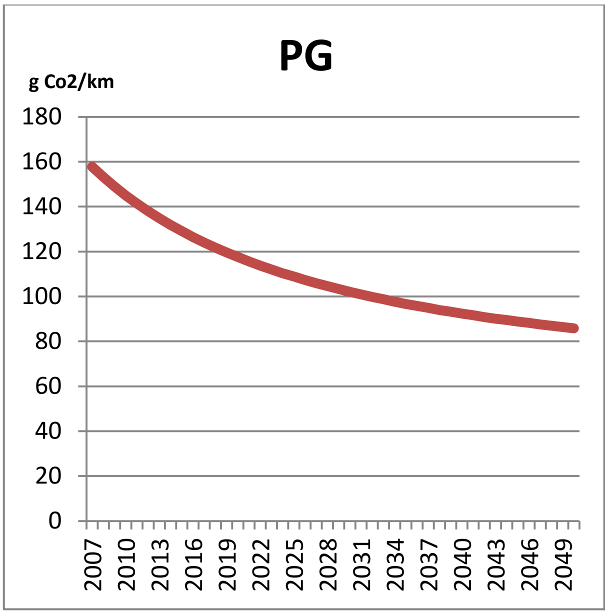


Figure 22: BMW Diffusion Curve



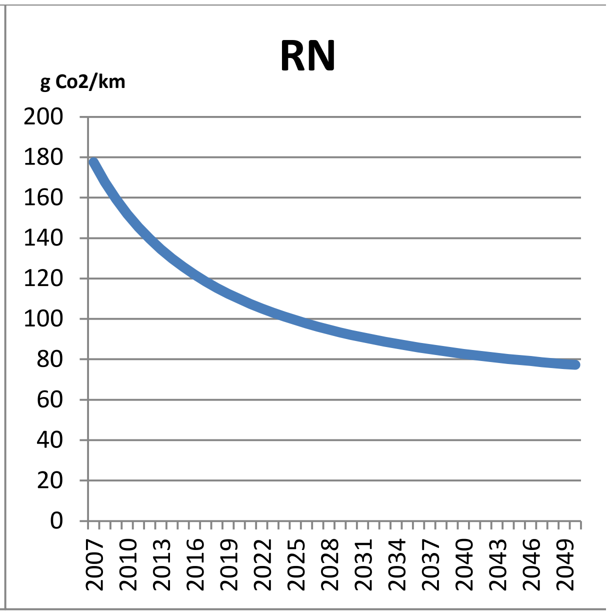
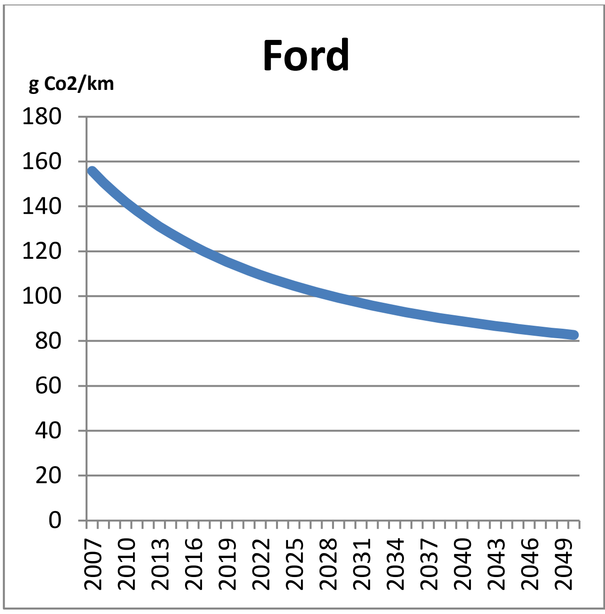


Figure 23: PG Diffusion Curve

Figure 24: RN Diffusion Curve



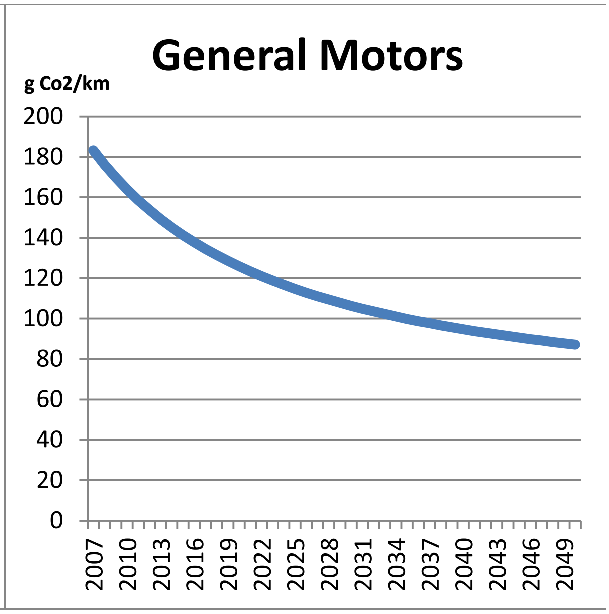


Figure 25: Ford Diffusion Curve

Figure 26: GM Diffusion Curve

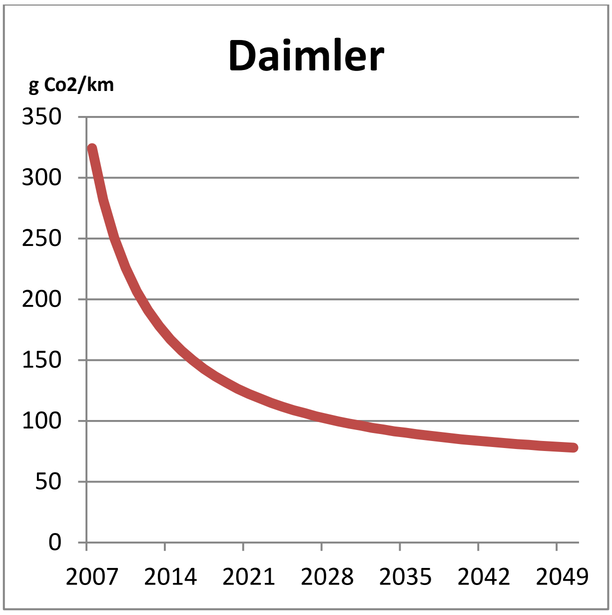


Figure 27: Daimler Diffusion Curve

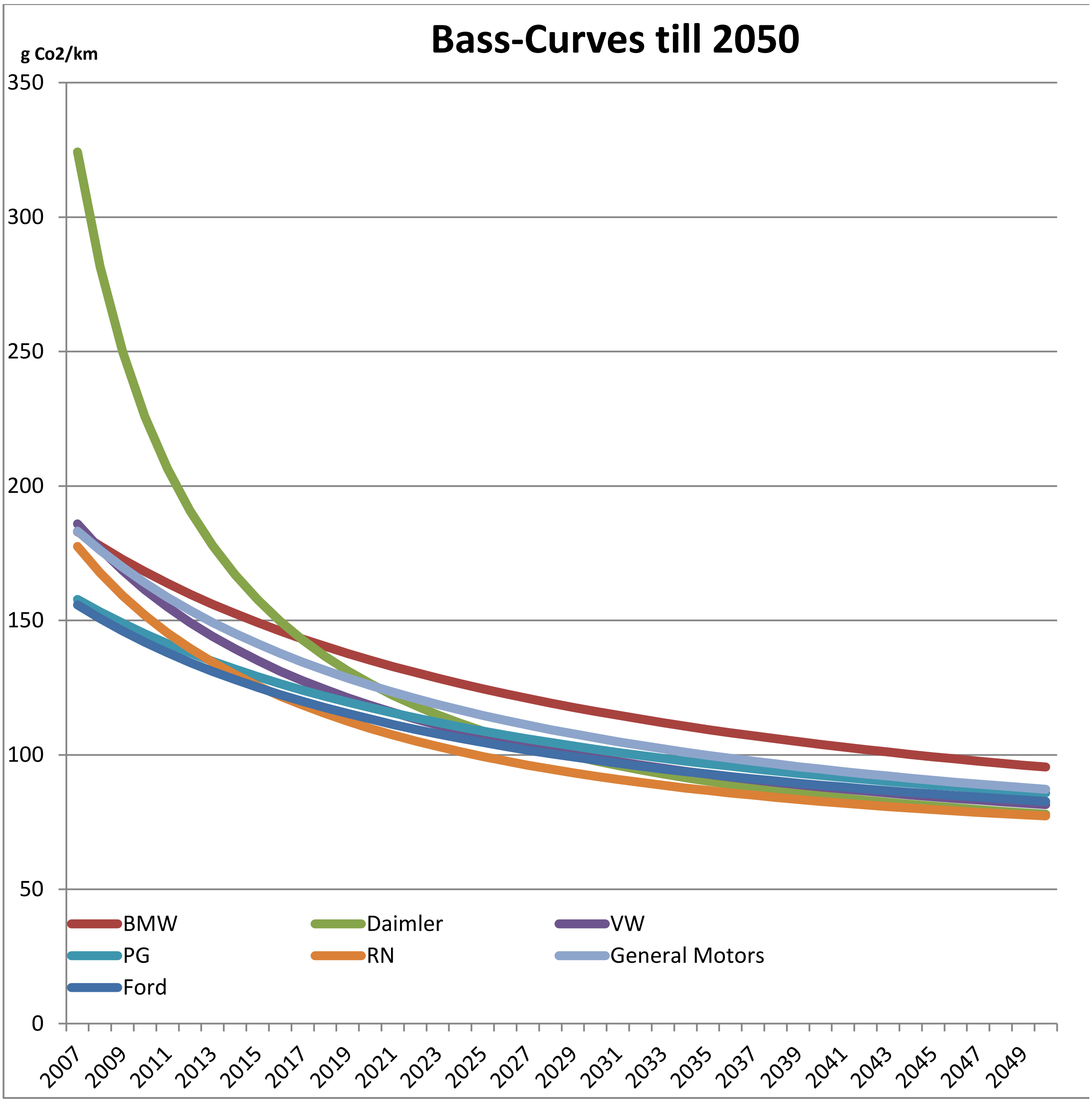


Figure 28: All Manufacturers Diffusion Curve

The various graphs show a similar as well as a comprehensible pattern, particularly an extremely improvement during the first years after the release of the statutory requirements paired with great effort by the participants in order to reach the determined targets. Furthermore the initially potential of technology improvement is higher once the research expenditure is increased in avoidance of the officially threatened punishments. Finally the illustrations shows a clear consistence with the Diffusion Model, which indicates that the values of the market participants are converging over time.

3.3 Bivariate analysis of the impact of lower emission values on stock prices

In this sub-section, the analysis is enhanced in that I am investigating whether the changes in the emission values for an individual car manufacturer have an impact on the stock value of this producer. The underlying hypothesis is that a reduction in the CO_2 emissions raises the long-term profitability of the company. Expectations of higher revenues will then be reflected in higher share prices with the result that there should be a negative causal relationship between CO_2 emissions and the share price. It is thus assumed that a causal relation exists between the stock price (SP) and the CO_2 emission (CO_2), with decreasing CO_2 emissions having a positive impact on the stock price. In other words, if the CO_2 emissions are decreasing, the stock market will reward these developments with increasing stock prices.

This hypotheses can be tested in terms of a regression model, with the following regression equation:

$$(1)\ SP(i,t) = \alpha + \beta * CO_2(i,t)$$

Equation 1

where :

SP(i,t) stock price of car manufacturer i in period t

CO_2(i,t) average CO_2 emission of new sold cars of manufacturer i in period t

α, β parameters, with $\alpha > 0$ and $\beta < 0$

Equation (1) reflects the long-term equilibrium between the share price and the CO_2 emission level. This nature of this long-term equilibrium is determined by the parameters α, β, where it is assumed that $\alpha > 0$, since the stock price cannot become negative, and $\beta < 0$ since, in line with the hypothesis formulated above, a fall in the CO_2 level will have a positive effect on the share price.

At any given moment of time, the long-term equilibrium between SP and CO_2 as described by equation (1) will be disturbed by the influence of various other effects (particularly the general state of the economy, firm-specific developments like technological innovations other than the introduction of more environmentally friendly engines, etc.). As there are many of these other influences which are unknown to us, the equation needs to be expanded by a random term, e(i,t), which encompasses the sum of all these other influences on the stock price:

$$(2)\ SP(i,t) = \alpha + \beta * CO_2\,(i,t) + e(i,t)$$

Equation 2

with:

e(i,t) random variable encompassing all other influences on the stock price

Since e(i,t) is the sum of a large number of random effects, which can be assumed to cancel each other out in the long term, the expected value of e, E(e(i,t)), is 0.

In a dynamic version of equation (2) lagged variables of the dependent, i.e. SP(i, t-1), SP(i, t-2), …, and of the independent variable, i.e. CO_2(i, t-1), CO_2(i, t-2), …, can be added.

The parameters α and β of equation (2) can be estimated with an appropriate statistical estimation method such as the Ordinary Least Squares (OLS). However, the problem with such an approach is that the stock price and the CO_2 emission are both variables that are likely to be subject to long-term trends. As Granger and Newbold (1974) have shown, an OLS regression framework where both the dependent and the independent variable are subject to a stochastic long-term trend can lead to "spurious correlation", i.e. a statistical significant relation between the dependent and independent variable will be detected although in reality such a relation does not exist. A time series which is subject to a stochastic trend is also said to possess a "unit root".[55]

[55] Cf. Granger & Newbold, 1974, p.111 ff

More formally, a time series x(t) is said to possess a unit root if it behaves like a random walk:

$$x(t) = x(t-1) + u(t)$$

with u(t) a random term.

If both SP and CO_2 possess a unit root we may thus get a statistically significant value for the parameter b, seemingly showing a causal relation between the share price and the CO_2 emission, although in reality such a relation does not exist. In the current context this possibility needs to be taken into account since numerous studies have shown that share prices do exhibit a unit root (for example: *"An Analysis of the Random Walk Hypothesis based on Stock Prices, Dividends, and Earnings"* by Risa Kavalerchik)[56]. Moreover, given the way CO_2 has been constructed it can be expected that also this variables exhibit a unit root.

Fortunately, as shown by Engle and Granger (1987), the problem of spurious correlation can be overcome under certain conditions by applying a so-called co-integration estimation framework. The condition under which a co-integration framework can be applied is that both the dependent and the independent variable are subject to a stochastic trend of the same order. The order of the stochastic trend – also called the degree of integration I(d) of a time series - is defined as the number of times it is necessary to difference a time series to eliminate the stochastic trend from the time series or, in other words, to make the series stationary. As an example, if the degree of integration of SP is I(1), the series which results from differencing SP once will lead to a stationary variable, i.e. the resulting variable is not anymore subject to a stochastic trend. In equation (3), subtracting x(t-1) from both sides results in

$$\Delta x(t)=x(t)-x(t-1)=u(t)$$

Since by assumption u(t) is stationary, x(t) is non-stationary of order I(1), i.e. can be made stationary by differencing once.[57]

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[56] Cf. Kavalerchik, 2010

[57] Cf. Engle & Granger, 1987, pp. 251-276

To determine whether the co-integration framework can be applied in the current context we thus have to find out whether SP and CO_2 are integrated of the same order I(d). This is equivalent to finding out whether SP and CO_2 include a unit root. For this purpose, the testing framework developed by Dickey and Fuller can be applied.

3.3.1 Dickey Fuller Tests for SP and CO_2

In the seventies D. Dickey and W. Fuller developed the so-called Dickey-Fuller test, which is often used in statistics and also known as unit root test. This procedure was constructed in order to test the null-hypothesis of a stochastic process with a unit root against the alternative of a process without a unit root.[58] [59]

The standard Dickey-Fuller (DF) test for a variable x(t) is realised by testing the null-hypothesis that x(t) has unit root, i.e. whether for the equation

$$x(t) = \rho * x(t-1) + u(t)$$

ρ equals 1. By subtracting y_{t-1} on both sides the equation can be rewritten as

$$\Delta x(t) = (\rho - 1) * x(t-1) + u(t) = \delta * x(t-1) + u(t)$$

in which case the null-hypothesis needs to be reformulated as H_O: $\delta = 0$.[60]

The test procedure is conducted in (up to three) consecutive steps where the procedure is stopped when a unit root has been ascertained in the previous step:

1. Random walk: $\Delta x(t) = \delta * x(t-1) + u(t)$
2. Random walk with intercept: $\Delta x(t) = a_0 + \delta * x(t-1) + u(t)$
3. Random walk with intercept and trend: $\Delta x(t) = a_0 + a_1 * T + \delta * x(t-1) + u(t)$

58 Cf. Dickey & Fuller, 1979, p. 427 ff
59 Cf. von der Lippe, Last accessed: 23.1.2016
60 Cf. Dickey & Fuller, 1979, p. 427 ff

The test procedure starts with a test of the null hypothesis that x(t) follows a simple random walk. If the null hypothesis is rejected, i.e. the assumption of a unit root is rejected by the test, a second test will be carried out assuming the underlying process is a random walk with intercept. By adding an intercept, which means the inclusion of a constant, kind of a gradient parameter (drift) is associated. If this test leads again to the rejection of the null hypothesis, a third test assuming that the underlying process is a random walk with intercept and deterministic trend (T) is carried out. In other words, the third procedure is regressed on a linear trend. [61]

The assumption that there is no unit root will only be accepted if all three steps of the test lead to the rejection of the unit root. In any other case the assumption of a unit root will be accepted.

In general, the DF test is based on the assumption that the error terms are uncorrelated. However, this presumption is not valid for most of the economic time series. Since auto-correlated error terms lead to distorted values for the test statistic, Dickey and Fuller suggest an expansion of the equation where lagged values of the dependent variable are added to the test equation. This is the Augmented Dickey Fuller (ADF) test which generalises the test-equation of the DF-test by adding lagged variable of the dependent variable[62]:

$$\Delta x(t) = \delta * x(t-1) + \theta_1 * \Delta x(t-1) + \dots + \theta_k * \Delta x(t-k) + u(t)$$

Similarly to the DF test, the ADF test is also carried out in three steps, with the second step adding an intercept to the test equation and the third step adding an intercept and a deterministic trend to the equation.[63]

The tests have been carried out with the econometric programme eViews. The test procedure used by eViews does not require the user to specify the number of lags as the lag-length is chosen optimally by the programme using the so-called Akaike information

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61 Cf. Stata, Last accessed: 23.1.2016

62 Cf. Harris, 1992, p.381 ff.

63 Cf. Hamilton, 1994, p.475 ff.

optimality criterion. (Given the automatic application of this test criterion I will not further refer to the number of lags included in each test equation.)

Table 5: Unit Root (ADF) Tests

		SP	Co2
VW	no Intercept, no Trend	0,3295	0,3198
RN	no Intercept, no Trend	0,2251	0,0945
	Intercept	-	0,4292
PG	no Intercept, no Trend	0,4834	0,0407
	Intercept	-	0,8581
GM	no Intercept, no Trend	0,6394	0,2679
FRD	no Intercept, no Trend	0,7486	0,192
DM	no Intercept, no Trend	0,644	0,0681
	Intercept	-	0,6906
BMW	no Intercept, no Trend	0,8681	0,3367

The results of the ADF test are summarised in Table 5. The values in the table indicate the confidence level at which the null-hypothesis can be rejected. As the critical threshold I determined the value of 0,10. That means, all results less than 10% could not be accepted and are therefore forwarded to step 2, where the test is executed again under the assumption that the underlying process is a random walk with intercept.

For instance, the value of 0,3295 (stock price for VW) indicates that rejecting the null-hypothesis of a unit root for the stock price of VW would be wrong in 33% of all cases. This error probability is much too high for which reason the null-hypothesis of the existence of a unit root is accepted.

The results show that the stock prices for all car manufacturers under investigation are subject to a unit root. In all cases the test procedure did not go beyond the first step, i.e. the stock prices exhibit a unit root without an intercept and a deterministic trend. As for the CO_2 emissions, again for all car manufacturers in the data set unit roots can be ascertained, but for some of the manufacturers (RN, PG, DM) the unit root is only accepted at the second step, i.e. after adding an intercept to the test equation. Renault with around 9%, Peugeot with approximately 4% and Daimler with nearly 7% have therefore not passed the criteria of 10%. Certainly, adding an intercept to the random walk resulted in clear results, which allowed the acceptance of the hypothesis. Consequently the existence of a unit root for all tested individuals has been noticed.

3.3.2 Co-integration analysis

Since the variable pairs (SP, CO_2) for all producers exhibit a unit root, a co-integration framework can be applied to test whether the evolution of the CO_2 emission has an impact on the share value for a specific car manufacturer.

Following Engle and Granger (1987), the co-integration framework can be implemented within a so-called error-correction model.[64] This is a two-step procedure, where in the first step equation (2) – which represents the long-term equilibrium between SP and CO_2. – is estimated with an appropriate method and the second step estimates the short-term dynamics with the help of the following equation:

$$(3)\ \Delta SP(i,t) = \gamma + \delta * \Delta CO_2(i,t) + \zeta * [SP(i,t-1) - \alpha - \beta * CO_2(i,t-1)] + u(i,t)$$

Equation 3

where:

$\Delta SP(i,t)$, $\Delta CO_2(i,t)$	change in the variable SP(i, t) and $CO_2(i,t)$
u(i,t)	random error term
γ, δ, ζ	estimation parameters with $\delta, \zeta < 0$

The parameter δ is expected to be negative since in line with the assumed negative long-term relation between SP and CO_2 a reduction in the CO_2 emission level is expected to lead to an increase in the stock price. The parameter ζ is the coefficient of the expression in square brackets, which is the period t-1 residual from the estimation of the long-term equilibrium (equation (2)). ζ is expected to be negative because it is assumed that a positive deviation of the actual stock price from the equilibrium stock price would lead to a negative correction in the next period and vice versa, i.e. a part of the "error" in the previous period is "corrected" in the current period.

64 Cf. Engle & Granger, 1987, p.252 ff

Estimation of long-term equation (2)

The estimation of equation (2) and (3) have been carried out with the programme eViews which offers the possibility to estimate a regression equation in a co-integration framework. The estimation routine takes into account serial correlation effects and the endogeneity in the regressors that result from the existence of a co-integrating relationship, i.e. uses the method of Fully Modified Ordinary Least Squares as developed originally by Phillips and Hansen (1990), and allows for the inclusion of a linear or quadratic trend.[65]

In order to make the estimation results comparable across producers the data used for the estimation of (2) and (3) needs to be standardised. By construction this is the case for CO_2 emission since these are official technical measures (however, the VW scandal has cast some doubt on this). But the stock values depend on a number of firm-specific parameters such as the currency of issuance, the face value per share, the length of the period during which the stock has been listed etc. To make the share prices comparable the stock values have therefore been normalised to yield an average of 100 for each producer, i.e. the stock prices have been divided by the average stock price for the producer over the period under consideration and multiplied by 100. Normalising the stock price in this way yields a straightforward interpretation for the (absolute value of the) parameter β: it shows the percentage deviation from the average stock price over the period under observation when the CO_2 emission level is reduced by one unit.

The estimation results are summarised in Table 6. Meaningful results, i.e. a statistically significant parameter β with the expected sign (-), have been achieved for five car manufacturers, namely RN, PG, FRD, DM and BMW. For two car manufacturers, the results were not meaningful in the sense that β was either not significant (this was the case for VW) or was significant but had the wrong sign (this was the case for GM). The results for the latter two manufacturers are therefore not shown in Table 6.

Apart from the parameter estimates for α and β, the table also shows whether the estimation procedure included a trend and the R^2, which is a measure for the overall

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[65] Cf. Phillips, 1995, p. 1023-1078

fit of the estimation. In the case of RN and BMW a quadratic trend has been included in the estimated equation to improve the overall fit.

The results show a relatively strong influence of the CO_2 emission level on the share price for RN and, to a lesser extent, PG, while for FRD, DM and BMW the influence is rather small.

Table 6: Estimation results for long-term equation (2)

	α	β	TREND	R-SQUARE
RN *T-STAT*	2212.69 *5.75*	-10.55 *-5.19*	QUADR	0.84
PG *T-STAT*	723.03 *3.16*	-4.21 *-2.71*		0.22
FRD *T-STAT*	494.72 *5.42*	-2.72 *-4.29*	-	0.46
DM *T-STAT*	794.91 *5.31*	-1.90 *-4.37*	-	0.65
BMW *T-STAT*	553.60 *7.26*	-2.68 *-5.95*	QUADR	0.59

When we compare these results with the results from the first part of the empirical analysis, i.e. the Bass-Diffusion model, it is notable that in both models manufacturers like BMW and DM are not very sensitive to high CO_2 values. The low β values, presented in the Table 6, show a low dependency of the CO_2 values in connection with the stock price. A similar pattern can be observed in the data of the Bass-Diffusion model, with initial values in 2007 of 309g CO_2/km for Daimler and 178g for BMW. In fact, these are very high emission values compared with their competitors, but as we know these two German car manufacturers had been competitive for many years. This implies again, that for these two manufacturers no strong correlation between "clean" engines and stock prices exist. However, due to the imposed regulations even these car brands are forced to produce more environmentally friendly cars. Indeed, these developments could lead to a competitive advantage in the near future, as these brands can promote their trusted brands with the positive supplement of eco-friendly engines.

The estimation results for the short-term dynamic equation (3) are summarised in Table 7. This equation can normally be used to project changes in the dependent variable (SP). However, as the results in Table 7 show, for all producers the parameter estimates for β, the coefficient linked with ΔCo2, is statistically insignificant, i.e. statistically not different from 0. This is not very surprising considering the construction of the variable: given the lack of monthly data, monthly intra-year changes were linearly interpolated, with the monthly increase set at 1/12 of the annual increase. Hence ΔCo2, which is constant during a year with a step change from one year to the next, does not have enough variation to be useful for short-term forecasting. The insignificance of the parameter does not mean that the CO_2 emission level does not have an impact on the stock price, it just means that with the data at hand we cannot detect the short-term dynamics between these two variables, while the long-term relation has already been established in the first step.

The entire short-term relation between SP and CO_2 comes from the error-correction term, with ζ significant and exhibiting the expected sign for all manufacturers for which a long-term relation could be established. The short-term equation thus shows that whenever there is a deviation from the long-term equilibrium relation between SP and CO_2 a part of this deviation is corrected in the next period. For RN, one third of the initial deviation is corrected in the next period, while for the other manufacturers the correction "speed" is significantly lower and lies between 8 (BMW) and 18 (DM) per cent.

Table 7: Estimation results for short-term dynamic equation (3)

	Γ	δ	ζ	R-SQUARE
RN	1.35	2.64	-0.33	0.23
T-STAT	*0.52*	*0.71*	*-4.87*	
PG	7.21	19.09	-0.15	0.08
T-STAT	*1.05*	*1.07*	*-2.51*	
FRD	4.08	9.39	-0.11	0.08
T-STAT	*1.56*	*1.57*	*-2.43*	
DM	-0.34	-0.23	-0.18	0.10
T-STAT	*-0.20*	*-0.31*	*-2.91*	
BMW	0.75	-0.20	-0.08	0.04
T-STAT	*0.72*	*-0.19*	*-1.88*	

4. Conclusion

The subject under investigation is a fairly new topic, as the mandatory regulation was only introduced during the last years. That is why the available data have to be considered carefully, since there are no long-term examined data on the field. A very current issue is the case of Volkswagen, which indicates that there is not a completely trustworthy use of data. Nevertheless, it is an extremely interesting theme to observe for the future, especially because environmental pollution is taking an important position in our modern life. In addition, the statutory regulation will strengthen the development of cleaner vehicles and the awareness of the market participants in regard to environmental friendly cars. Even the society as a whole evolves in a more environmental-conscious direction, which will contribute to further promote this topic in the near future. This empirical investigation should deliver a first insight concerning the correlation of CO2 emission values and the profitability of the companies in this industry. The results provided some very interesting outcomes, in particular the long-term correlation between the stock prices of the car manufacturers and their decreasing CO2 emissions. The used model, namely the co-integration analysis, seems to be a useful approach to observe the given patterns. Especially, the beginnings of this new period in the automobile industry will be exciting to notice, as the interplay of legal restrictions, more efficient technologies and customer-orientation towards environmental-friendly vehicles could rearrange this industry from the bottom up. The second major investigation in this paper was concerned with the Diffusion of the CO2 emissions after the announcement of the new legislation. Conducted with a Bass-Diffusion-Model I examined which manufacturer is able to customize its emissions most rapidly in order to fulfil the required values. The investigation brought some plausible outcomes, for example that Daimler has the highest growth factor concerning the reduction of its emission values, which is owed to the fact of a very high present value. The remaining manufacturers, which have similarly starting values, completed the test with no significant results, attributed to no substantial technological advantage in the peer group.

For further research, one must hope that the transparency of the individual manufacturers data will be enhanced and thereby the accuracy of such comparisons can be improved. The technological development should deliver exciting progresses, in particular when the market participants have reached a common level and the next step of innovation will come into effect. Additionally, the convergence of the electronic car industry to the mass market will occupy a crucial part of the automobile market and should be considered in further studies.

Annex: Tables

Table 8: Calculation of the group value for BMW

BMW Group

2007	Sales (tsd.)	Group-Share	Co2 g/km	weighted Co2
BMW	1277	0,851	186	158,348
Mini	223	0,149	131	19,475
Totals	1500	1,000	158,5	**177,823**

2008	Sales (tsd.)	Group-Share	Co2 g/km	weighted Co2
BMW	1202	0,838	195	163,452
Mini	232	0,162	128	20,709
Totals	1434	1,000	158,5	**184,160**

2009	Sales (tsd.)	Group-Share	Co2 g/km	weighted Co2
BMW	1069	0,831	170	141,314
Mini	217	0,169	131	22,105
Totals	1286	1,000	150,5	**163,419**

2010	Sales (tsd.)	Group-Share	Co2 g/km	weighted Co2
BMW	1224	0,840	186	156,148
Mini	234	0,160	131	21,025
Totals	1458	1,000	158,5	**177,173**

2011	Sales (tsd.)	Group-Share	Co2 g/km	weighted Co2
BMW	1380	0,829	186	154,162
Mini	285	0,171	134	22,937
Totals	1665	1,000	160	**177,099**

2012	Sales (tsd.)	Group-Share	Co2 g/km	weighted Co2
BMW	1540	0,836	154	128,751
Mini	302	0,164	138	22,625
Totals	1842	1,000	146	**151,377**

2013	Sales (tsd.)	Group-Share	Co2 g/km	weighted Co2
BMW	1655	0,844	153	129,191
Mini	305	0,156	138	21,474
Totals	1960	1,000	145,5	**150,666**

Table 9: Calculation of the group value for Peugeot

Peugeot Group

2007	Sales (tsd.)	Group-Share	Co2 g/km	weighted Co2
Peugeot	1304	0,528	144	76,053
Citroen	1165	0,472	174	82,102
Totals	2469	1,000	159	**158,156**

2008	Sales (tsd.)	Group-Share	Co2 g/km	weighted Co2
Peugeot	1199	0,530	135	71,495
Citroen	1065	0,470	168	79,028
Totals	2264	1,000	151,5	**150,523**

2009	Sales (tsd.)	Group-Share	Co2 g/km	weighted Co2
Peugeot	1164	0,528	136	71,761
Citroen	1042	0,472	166	78,410
Totals	2206	1,000	151	**150,170**

2010	Sales (tsd.)	Group-Share	Co2 g/km	weighted Co2
Peugeot	1175	0,537	132	70,887
Citroen	1013	0,463	166	76,855
Totals	2188	1,000	149	**147,741**

2011	Sales (tsd.)	Group-Share	Co2 g/km	weighted Co2
Peugeot	1087	0,534	130	69,474
Citroen	947	0,466	151	70,303
Totals	2034	1,000	140,5	**139,777**

2012	Sales (tsd.)	Group-Share	Co2 g/km	weighted Co2
Peugeot	950	0,536	130	69,735
Citroen	821	0,464	147	68,146
Totals	1771	1,000	138,5	**137,881**

2013	Sales (tsd.)	Group-Share	Co2 g/km	weighted Co2
Peugeot	893	0,543	126	68,442
Citroen	751	0,457	144	65,781
Totals	1644	1,000	135	**134,223**

Table 10: Calculation of the group value for Renault

Renault Group

2007	Sales (tsd.)	Group-Share	Co2 g/km	weighted Co2
Renault	1575	0,897	180	161,485
Dacia	181	0,103	159	16,355
Totals	1756	1,000	169,5	**177,840**
2008	**Sales (tsd.)**	**Group-Share**	**Co2 g/km**	**weighted Co2**
Peugeot	1433	0,881	173	152,331
Citroen	194	0,119	161	19,235
Totals	1627	1,000	167	**171,566**
2009	**Sales (tsd.)**	**Group-Share**	**Co2 g/km**	**weighted Co2**
Renault	1340	0,841	155	130,340
Dacia	253	0,159	152	24,183
Totals	1593	1,000	153,5	**154,523**
2010	**Sales (tsd.)**	**Group-Share**	**Co2 g/km**	**weighted Co2**
Renault	1419	0,835	150	125,219
Dacia	281	0,165	147	24,285
Totals	1700	1,000	148,5	**149,504**
2011	**Sales (tsd.)**	**Group-Share**	**Co2 g/km**	**weighted Co2**
Renault	1338	0,833	145	120,819
Dacia	268	0,167	146	24,347
Totals	1606	1,000	145,5	**145,500**
2012	**Sales (tsd.)**	**Group-Share**	**Co2 g/km**	**weighted Co2**
Renault	1068	0,832	139	115,654
Dacia	216	0,168	143	24,017
Totals	1284	1,000	141	**139,672**
2013	**Sales (tsd.)**	**Group-Share**	**Co2 g/km**	**weighted Co2**
Renault	1036	0,767	135	103,519
Dacia	315	0,233	145	33,813
Totals	1351	1,000	140	**137,332**

Table 11: Calculation of the group value for Ford

Ford Group

2007	Sales (tsd.)	Group-Share	Co2 g/km	weighted Co2
Ford	1583	0,807	148	119,410
Land Rover	112	0,057	185	10,582
Volvo	267	0,136	203	27,603
Totals	1962	1,000	178,67	157,595

2008	Sales (tsd.)	Group-Share	Co2 g/km	weighted Co2
Ford	1473	0,868	141	122,366
Volvo	224	0,132	197	26,034
Totals	1697	1,000	112,67	148,401

2009	Sales (tsd.)	Group-Share	Co2 g/km	weighted Co2
Ford	1459	0,876	141	123,522
Volvo	206	0,124	196	24,296
Totals	1665	1,000	112,33	147,818

2010	Sales (tsd.)	Group-Share	Co2 g/km	weighted Co2
Ford	1296	1,000	139	139,000
Totals	1296	1,000	139	139,000

2011	Sales (tsd.)	Group-Share	Co2 g/km	weighted Co2
Ford	1278	1,000	137	137,000
Totals	1278	1,000	137	137,000

2012	Sales (tsd.)	Group-Share	Co2 g/km	weighted Co2
Ford	1112	1,000	137	137,000
Totals	1112	1,000	137	137,000

2013	Sales (tsd.)	Group-Share	Co2 g/km	weighted Co2
Ford	1090	1,000	131	131,000
Totals	1090	1,000	131	131,000

Table 12: Calculation of the group value for GM

GM Group

2007	Sales (tsd.)	Group-Share	Co2 g/km	weighted Co2
Chevrolet	221	0,123	158	19,388
Opel	1496	0,831	183	152,009
Saab	84	0,047	214	9,981
Totals	1801	1,000	185	**181,378**
2008	**Sales (tsd.)**	**Group-Share**	**Co2 g/km**	**weighted Co2**
Chevrolet	188	0,122	155	18,849
Opel	1294	0,837	185	154,845
Saab	64	0,041	208	8,611
Totals	1546	1,000	182,67	**182,304**
2009	**Sales (tsd.)**	**Group-Share**	**Co2 g/km**	**weighted Co2**
Chevrolet	191	0,141	151	21,316
Opel	1137	0,840	171	143,701
Saab	25	0,018	202	3,732
Totals	1353	1,000	174,67	**168,749**
2010	**Sales (tsd.)**	**Group-Share**	**Co2 g/km**	**weighted Co2**
Chevrolet	179	0,142	148	20,975
Opel	1084	0,858	162	139,040
Totals	1263	1,000	155	**160,016**
2011	**Sales (tsd.)**	**Group-Share**	**Co2 g/km**	**weighted Co2**
Chevrolet	176	0,140	146	20,426
Opel	1082	0,860	157	135,035
Totals	1258	1,000	151,5	**155,461**
2012	**Sales (tsd.)**	**Group-Share**	**Co2 g/km**	**weighted Co2**
Chevrolet	172	0,159	144	22,891
Opel	910	0,841	155	130,360
Totals	1082	1,000	149,5	**153,251**
2013	**Sales (tsd.)**	**Group-Share**	**Co2 g/km**	**weighted Co2**
Chevrolet	142	0,137	144	19,680
Opel	897	0,863	155	133,816
Totals	1039	1,000	149,5	**153,497**

Abstract:

This working paper presents one of the first investigations regarding a relatively new development in the passenger car industry, the reduction of CO_2 emissions in conjunction with the profitability of the companies. Due to legal regulations the manufacturers are forced for the first time to adjust its products to official emission limitations. Initially, a theoretical bases is given in order to explain the later discussed parameters as well as the developments and the determination by the guardians of the EU law.

The empirical part should provide knowledge concerning the on-going developments of the particular manufacturers. The first of the two main empirical investigations deals with a Bass-Diffusion-Model, which is going to recognize the participant with the highest speed of adoption after the release of new market circumstances. The second part is concerned with a co-integration model, which should provide insights if the stock market will reward the developments of decreasing CO_2 emissions with increasing stock prices.

The Bass-Diffusion-Model delivers no significant conclusion, only the expected confirmation, that car manufacturers like Daimler with high initial CO_2 values are adopting the legal regulations with the highest speed. The co-integration analysis delivers substantial results, which show that there is coherence in the long-term between CO_2 emission reduction and stock prices.

Keywords :

#CO_2-Emission #Stock Prices #Car Manufacturer #EU Regulation #Bass-Diffusion-Modell #Co-Integration Analysis

Kurzzusammenfassung (Abstract)

Diese Masterarbeit beschäftigt sich mit einem sehr jungen sowie aktuellen Thema, nämlich der CO_2 –Emissions-Reduzierung in der Personenkraftfahrzeug Industrie in Bezug auf deren wirtschaftlichen Auswirkungen. Durch die gesetzlich verpflichtende Einführung von Emissionsuntergrenzen, stehen die Hersteller erstmals an einem kritischen Punkt der Veränderung in diesem Bereich. Im theoretischen Teil wird die Grundlage für die später verwendeten CO_2 Werte gebildet, sowie die Entwicklungen der Europäischen Gesetzgebung beschrieben. Der empirische Teil untersucht die derzeitigen Entwicklungen der einzelnen Hersteller bezüglich ihrer Anpassungsgeschwindigkeit sowie den Zusammenhang mit den jeweiligen Aktienkursen. Der erste von zwei Teilen beschäftigt sich mit dem sogenannten Bass-Diffusions-Modell, welches die Adaptionsgeschwindigkeit der Automobilkonzerne anhand der veränderten CO_2 Werte, nach Veröffentlichung der neuen Grenzwerte aus den EU-Richtlinien, misst. Der zweite Teil stellt ein Co-Integrationsmodell dar, worin untersucht wird ob der Aktienmarkt den Aufwand von verbesserten Fahrzeugen, im speziellen von geringeren CO_2 Werten, durch einen Anstieg des jeweiligen Herstellers belohnt.

Die Ergebnisse des Bass-Diffusions-Modell brachten keine signifikanten Ergebnisse, was eventuell auf die sehr junge Thematik zurückzuführen ist. Da die gesetzlichen Auflagen sehr zögernd und lasch umgesetzt wurden und auch bei den CO_2 Werten noch keine klare Linie vorherrscht, kann dies als Erklärung der herangezogen werden. Allerdings, bestätigte sich das Modell in der Hinsicht das Konzerne wie Daimler, mit sehr hohen Anfangsemissionen den höchsten Anpassungswert erreichten. Die Co-Integrationsanalyse brachte mitunter sehr aufschlussreiche Resultate, welche einen langfristigen Zusammenhang zwischen fallenden Co2-Emissionswerten und dadurch steigenden Aktienkursen ergab.

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